93-e44

Spatial and Temporal Trends in Contaminant Levels in Settling Particulate Matter: Thea Foss Waterway (Commencement Bay) - June 1989 to November 1992

by
Dale Norton

Washington State Department of Ecology
Environmental Investigations and Laboratory Services Program
Toxics Investigations Section
Olympia, WA 98504-7710

Water Body No. WA-10-0020
(Segment No 05-10-01)

August 1993

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLE (Continued)

Appendices

LIST OF FIGURES

ACKNOWLEDGEMENTS

Many individuals have made valuable contributions to the Thea Foss Waterway sediment trap monitoring project. Although it is not possible to acknowledge all participants, the authors would like to extend special thanks to the following individuals:

- Stuart Magoon and Dickey Huntamer of the Ecology/EPA Manchester Laboratory for their technical assistance in designing the analytical scheme, coordinating the organics analyses, and reviewing the analytical results.
- Bill Kammin, also of the Manchester Laboratory, for reviewing the results of metals analysis on samples collected between November 1991 and November 1992.
- Eric Crecelius of the Battelle Northwest Sequim Laboratory for conducting the metals analysis for the project.
- Bob Barnard for constructing the sediment traps, assisting in the field collections and processing data.
- Jim Cubbage, Dave Serdar, Bernie Strong, Kitty Bickle, John Tooley, Dan Saul, Dale Davis, and Dickey Huntamer for their assistance in the field collections.
- Bill Yake, Greg Pelletier, Dave Smith, Sandy Stevens, Russ McMillan, and Marv Coleman reviewed the draft report and provided many valuable comments.
- Carol Janzen for her assistance in the CTD profiling and associated data processing.
- Kelly Carruth for typing and proofing the document.

EXECUTIVE SUMMARY

To evaluate the effectiveness of efforts to control sources of problem chemicals to Thea Foss Waterway, samples of settling particulate matter (SPM) and in-place bottom sediments were collected between June 1989 and November 1992. All SPM samples were collected with the use of moored sediment traps. Chemical analyses focused on "problem" metals and organics, which were identified for Thea Foss Waterway during the Commencement Nearshore/Tideflats Remedial Investigation (Tetra Tech, 1985).

Mean concentrations of ten individual problem chemicals in SPM were high enough to adversely affect marine benthic communities, based on comparisons with the Commencement Bay Sediment Quality Objectives (SQOs). The greatest number of exceedences (9) were measured at the head of the waterway near the twin 96" drains. "Problem" chemicals with average concentrations in SPM exceeding the SQOs are listed below;

Location	Chemical
• TF-1 (Head)	Copper, mercury, zinc, LPAH, HPAH, phenol, 4-methyl phenol, butyl benzyl phthalate, and bis (2-ethyl hexyl) phthalate
• TF-2	Copper, mercury, phenol, bis (2-ethyl hexyl) phthalate, and benzyl alcohol
• TF-3	Copper, mercury, LPAH, HPAH, phenol, bis (2-ethyl hexyl) phthalate
• TF-4 (Mouth)	4-methyl phenol, bis (2-ethyl hexyl) phthalate, and benzyl alcohol

In addition, average SPM concentrations of four non-priority (benzoic acid, diethyl phthalate, dimethyl phthalate, and di-n-butyl phthalate) chemicals were also measured above the SQOs. Tributyltin concentrations in SPM exceeded the Puget Sound Dredge Disposal Analysis Interim Screening Level of 30 ug/kg at all locations in Foss Waterway.

Relatively high concentrations (up to 11%) of total organic carbon (TOC) were also present in Foss Waterway, especially at the head. While no SQO is available to evaluate TOC levels, these concentrations are high enough to potentially pose problems for benthic infauna.

The spatial distribution of priority contaminants measured in both SPM and bottom sediments during the present study is in relatively good agreement with historical information on sediment contamination in Thea Foss Waterway. The highest concentrations of most problem chemicals (metals and organics) were present at the head and the lowest were typically measured at the mouth of the waterway. Exceptions to this general pattern were mercury near the 15th Street drain; copper and mercury near the mouth of Wheeler-OsgoodWaterway; and 4-methyl phenol at the mouth, which were at a maximum at the locations indicated.

Mercury data for SPM indicates that concentrations at the head of the waterway and near the 15th Street drain have increased almost two-fold since sediment trap monitoring began in late 1988. At a minimum the increasing trends for mercury are statistically significant at the 95% confidence level. This finding is consistent with the fact that, on average, bottom sediments collected in 1988 and 1989 at these two locations also have higher mercury concentrations compared to samples taken in 1984.

Overall, the data collected suggest that concentrations of most problem chemicals in Thea Foss Waterway sediments have not decreased since the Commencement Bay Remedial Investigation was conducted in 1984. A possible exception is lead at the head of the waterway which appears to be lower but is still above the SQO. These results are not unexpected since few source controls have actually been implemented in the waterway as of April 1993. The current schedule calls for source control to be completed in Foss Waterway by December 1994 (Smith, 1993).

Sedimentation rates for Thea Foss Waterway calculated from sediment trap data ranged from 0.2-5.0 $g/cm^2/yr$ with a mean of 1.7 ± 1.1 $g/cm^2/yr$. Average bottom sediment resuspension rates were estimated to be 1.3 and 1.1 $g/cm^2/yr$ at the head and mouth, respectively. These data suggest that 70-80 percent of the material collected by the traps, could be recently deposited particulates which have not yet been consolidated on the bottom. Vessel activities could play an important role in resuspending sediments in Thea Foss Waterway. While the exact proportion of "new" vs. "old" material being collected by the traps cannot be reliably determined with the available data, it is fair to assume that the material collected is representative of sediments which are mobile in the waterway.

Current velocities were generally slow in the waterway during deployment of the current meters (spring tidal series), ranging from 2-28 cm/sec with a geometric mean of 2.3 cm/sec. The lowest velocities were measured at the head of Thea Foss Waterway, where currents are ≤ 4 cm/sec 90% of the time. This result implies that poor flushing characteristics are present at the head of the waterway. For comparison, velocities reported for other Commencement Bay waterways between December 27, 1990, and February 5, 1991, were as follows: Hylebos 2-85 cm/sec, Geo. mean= 5.5 cm/sec; Sitcum 2-150 cm/sec, Geo. mean= 3.4 cm/sec.

RECOMMENDATIONS

Based on the results of this study the following recommendations are made;

- Re-evaluate potential sources of mercury in the upper half of Foss Waterway, with emphasis on the areas around the twin 96" drains and the 15th Street drain. Mercury sources need to be located and controlled prior to performing sediment remediation in the waterway.

- Re-calculate natural recovery rates for problem chemicals in Thea Foss Waterway bottom sediments, based on sediment accumulation and chemistry data presented here. This information should be incorporated into the remedial design for cleaning up contaminated sediments in the waterway.

- While a number of administrative actions have occurred to begin the process of reducing the input of problem chemicals to the waterway, few source controls have actually been completed as of April 1993. Any further source control activities (*i.e.* verify that known sources are controlled and unknown sources are not present) in the waterway should focus on areas of the waterway where concentrations of problem chemicals in SPM exceeded the SQOs. These areas are shown below:

Location	Chemical
• TF-1 (Head)	Copper, mercury, zinc, LPAH, HPAH, phenol, 4-methyl phenol, butyl benzyl phthalate, and bis (2-ethyl hexyl) phthalate
• TF-2	Copper, mercury, phenol, bis (2-ethyl hexyl) phthalate, and benzyl alcohol
• TF-3	Copper, mercury, LPAH, HPAH, phenol, bis (2-ethyl hexyl) phthalate
• TF-4 (Mouth)	4-methyl phenol, bis (2-ethyl hexyl) phthalate, and benzyl alcohol

- Tributyltin (TBT) should be added to the list of chemicals of concern for Foss Waterway based on a comparison of concentrations in SPM with the Puget Sound Dredge Disposal Analysis Interim Screening Level of 30 ug/kg. Under PSDDA TBT concentrations above 30 ug/kg in sediments would require biological testing to be performed.

- A limited amount of information is available in the central part of the waterway on net sedimentation rates. If additional cores are collected in this area of the waterway for chemical characterization purposes, net sedimentation rates should be determined using Pb-210 techniques.

INTRODUCTION

Thea Foss Waterway (formerly City Waterway), shown in Figure 1, is one of seven waterways, which along with the Puyallup River mouth make up the tideflats portion of the Commencement Bay Nearshore/Tideflats (CB/NT) Superfund Site. Contamination of Thea Foss Waterway bottom sediments with a variety of chemicals was documented during the CB/NT Remedial Investigation (RI), (Tetra Tech, 1985). A list of problem chemicals for Thea Foss Waterway was also identified during this study. This list, shown in Table 1 has recently been clarified by Region 10 of the Environmental Protection Agency (EPA) after re-evaluating the data generated during the CB/NT RI (EPA, 1992). For informational purposes only, also shown in Table 1 are indicator chemicals. Indicator chemicals were selected from the list of problem chemicals for each waterway to be representative of major sources and show similar geographic trends as other major problem chemicals from the same source. Indicator chemicals were only used in the CB/NT Feasibility Study (FS) to estimate areas and volumes of sediment requiring remediation (EPA, 1992).

As a result of the CB/NT RI and subsequent studies, source control programs aimed at reducing contaminant loadings to the waterway have been implemented by the Department of Ecology, City of Tacoma and the Tacoma-Pierce County Health Department. The schedule for implementing source identification and control in Thea Foss Waterway is described in the CB/NT Record of Decision (ROD), Appendix C (EPA, 1989a). It is worth mentioning that as of April 1993 source discovery work has been completed in Foss Waterway, however very few source controls have actually been installed (Smith, 1993). Several noteworthy exceptions that have occurred during the course of the present study are listed below;

- A system to treat contaminated groundwater and extract vapors from contaminated soils at the D-Street Tank Farms began full operation in late October 1992;
- The city of Tacoma removed contaminated sediments in 1991 from several storm drains that discharge to the waterway; and
- An NPDES permit has been issued at J.M. Martinac Shipbuilding to institute best management practices and begin controlling contaminated stormwater from the facility.

In 1988 Ecology's Commencement Bay Urban Bay Action Team (UBAT) requested that the Toxics, Compliance and Ground Water Investigations Section conduct a sediment study to monitor the progress of source control activities in Thea Foss Waterway. The objectives of this study are listed below:

- Determine the concentrations of problem chemicals associated with settling particulate matter (SPM) in Thea Foss Waterway; and
- Estimate present sedimentation rates in the waterway.

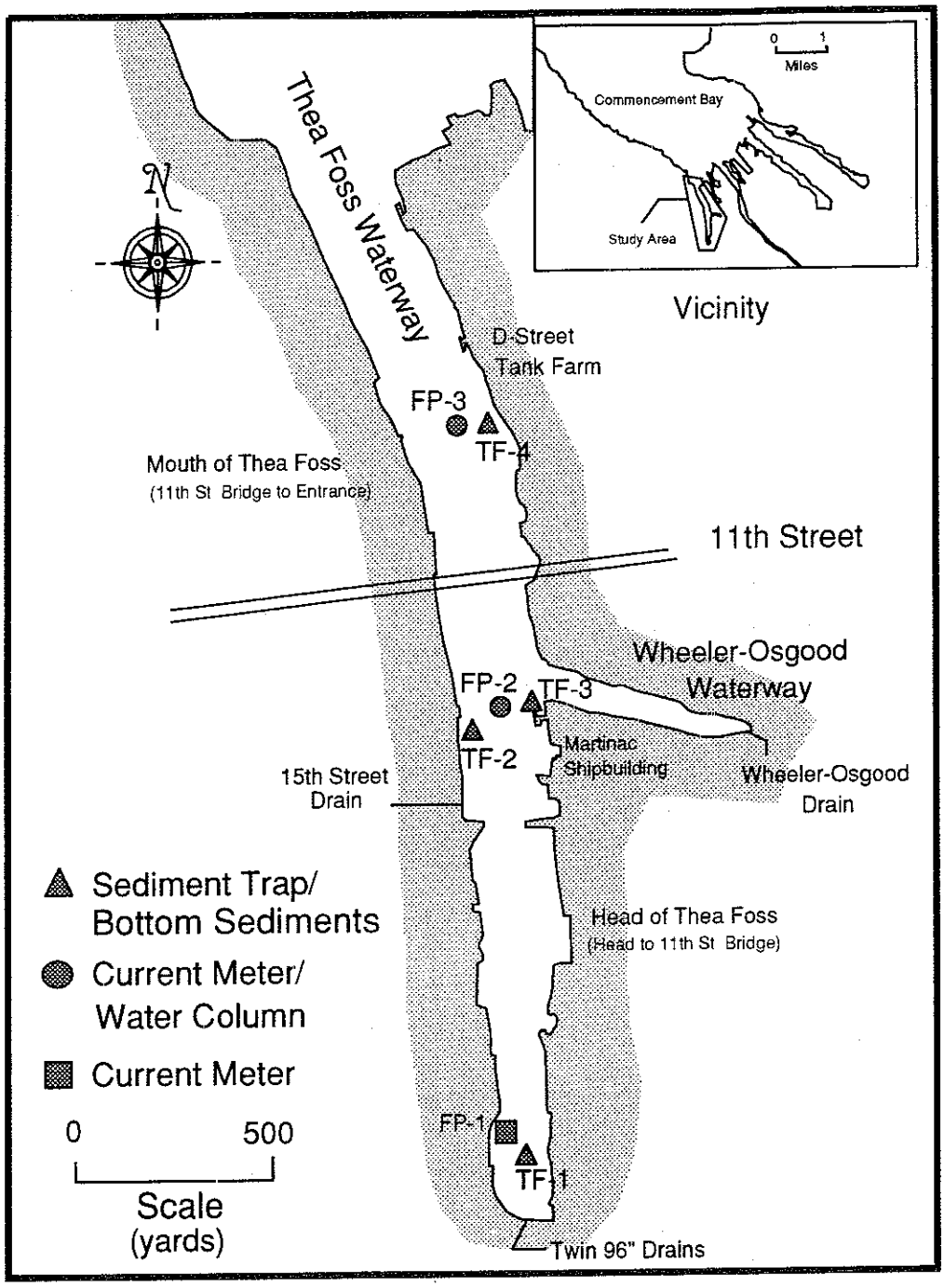

Figure 1: Station Locations for Thea Foss Sediment Trap Monitoring Project.

Table 1: Summary of problem chemicals(1) in Thea Foss Waterway

I. Head of Thea Foss (Head to 11th Street Bridge)

Priority			Indicator
1	2	3	Chemicals*
TOC	Oil and Grease	1,4-Dichlorobenzene	HPAH
Mercury	Cadmium	N-Nitrosodiphenylamine	Cadmium
Lead	Copper	Aniline	Lead
Zinc	Nickel	Benzyl alcohol	Mercury
	LPAH	Phenol	
	HPAH		
	2-Methylphenol		
	4-Methylphenol		
	Bis(2-ethyl hexyl) phthalate		
	Butyl benzyl phthalate		

II. Mouth of Thea Foss (11th Street Bridge to Mouth)

Priority			Indicator
1	2	3	Chemicals*
-	LPAH	Mercury	HPAH
	HPAH	Zinc	Mercury
		Dibenzothiophene	
		Phenol	
		Biphenyl	
		PCBs	

III. Wheeler-Osgood Waterway

Priority			Indicator
1	2	3	Chemicals*
-	TOC	-	Zinc
	Cadmium		HPAH
	Copper		
	Lead		
	Zinc		
	LPAH		
	HPAH		
	Biphenyl		
	Phenol		
	4-Methylphenol		
	1,2-Dichlorobenzene		
	N-Nitrosodiphenylamine		

(1)=Problem chemicals identified during the Commencement Bay Remedial Investigation (clarified by EPA, 1992)

*=See text for discussion of indicator chemicals

The results of this investigation will be used, along with other available information in Commencement Bay, to evaluate the effectiveness of source control efforts in reducing the input of problem chemicals to Foss Waterway, determine when source control has been achieved, and aid in selecting remediation options for sediments.

Sediment trap monitoring in Thea Foss Waterway began in November 1988. Results from the first six months of monitoring have been previously reported in Norton (1990). The present paper reports data collected between June 1989 - November 1992 (2.5 years). Results from monitoring conducted after November 1992 will be reported in subsequent updates. Similar monitoring efforts are also being conducted by Ecology concurrently in Sitcum and Hylebos Waterways. Results from monitoring conducted between July 1990 and June 1991 in Sitcum Waterway; and July 1990 to November 1991 in Hylebos Waterway are currently available (Norton and Barnard, 1992a,b).

METHODS

Sample Collection

To characterize present conditions in Thea Foss Waterway, water samples, current velocity measurements, SPM, and bottom sediments were collected between May 30, 1989, and November 17, 1992. Sampling locations, shown in Figure 1, were selected to provide a broad spatial coverage of the waterway, and to the extent possible, correspond to major contaminant sources identified during the CB/NT RI. Detailed descriptions of each sampling location are provided in Table 2. Station positions were located using a Magellan® Model 11001 Nav 1000 Plus GPS receiver, in conjunction with depth readings.

Water Sampling

To help interpret the distribution of particulates in the waterway, samples for total suspended solids (TSS) determinations were obtained at two mid-channel stations (Figure 1) with a Van Dooren Bottle between August 30, 1989, and June 19, 1991. In addition, between October 1990 and November 1991 continuous vertical profiles of temperature, salinity, and light transmittance were collected concurrently with the TSS samples during deployment and retrieval of the sediment traps (quarterly). Temperature, salinity and light transmittance were measured with a Seabird Electronics SEACAT® Model SBE-19 Profiler equipped with a Sea Tech, Inc. 25cm Beam Transmissometer.

Current Velocity Measurements

To characterize current velocities in Thea Foss Waterway, two Aanderra® Current Meters Model RCM-4 were deployed for approximately one month (May 30 to June 29, 1989) at stations FP-2 and FP-3 (Figure 1). To increase spatial coverage of the waterway, a third deployment was made between July 2 and August 13, 1991, at station FP-1 which is located at the head of the waterway.

Table 2: Station locations for Thea Foss sediment trap monitoring project, June 1989 to November 1992.

Station No.	Latitude			Longitude			Description	Total Water Depth (ft @ MLLW)	Sample Type
TF-1	47	14	34	122	25	49	Thea Foss @ Head Near Twin 96" Drains	18	SPM,BS
TF-2	47	15	5	122	25	57	Thea Foss North of 15th Street Drain	20	SPM,BS
TF-3	47	15	6	122	25	51	Thea Foss @ Mouth of Wheeler-Osgood Waterway	30	SPM,BS
TF-4	47	15	26	122	25	56	Thea Foss @ Mouth near D-Street Tank Farms	25	SPM,BS
FP-1	47	14	33	122	25	51	Thea Foss Mid-Channel at Head	20	CM
FP-2	47	15	6	122	25	52	Thea Foss Mid-Channel Between TF-2 and TF-3	24	WC,CM
FP-3	47	15	26	122	25	56	Thea Foss Mid-Channel @ Mouth	30	WC,CM

Lat/Long= (degrees/minutes/seconds)
SPM= Settling Particulate Matter
BS= Bottom Sediment
WC= Water Column Profile
CM=Current Meter

All of these meters were moored three feet above the bottom. Deployment of the meters was timed to coincided with periods of maximum tidal exchange (spring tidal series). Each meter was set at a recording interval of 15 minutes.

SPM Sampling

SPM was collected at four locations in the waterway with the use of moored sediment traps, positioned three feet above the bottom. Total depths in the sampling area ranged from approximately 18 to 30 feet at mean lower low water (MLLW). The sediment traps in Thea Foss Waterway were initially deployed on November 10, 1988, and sampled every three months thereafter (*i.e.*, quarterly).

Sediment traps have been used widely in the oceans to measure the vertical transport of materials with results that are in good agreement with data obtained using different scientific approaches (Buesseler, 1991; and USGOFS, 1989). The traps used in the present study are straight-sided glass cylinders with a collection area of 78.5 cm^2 and a height-to-width ratio of five. Previous studies have shown that cylindrical sediment traps with these characteristics would provide unbiased samples of the vertical particle flux in current velocities expected to occur in Thea Foss Waterway (Butman, 1986; Butman *et al.*, 1986; Baker, *et al.*, 1988; and Larsson, *et al.*, 1986). In addition, these traps have been used by Ecology between 1988-1992 to monitor contaminant levels in Thea Foss, Hylebos and Sitcum Waterways with excellent results (Norton, 1990; Norton and Barnard, 1992a,b). A schematic of the construction details of the traps and their moorings is presented in Appendix A- Figure A1.

At deployment, the traps were filled with two liters of high salinity water (4% NaCl), which contained sodium azide (2%) as a preservative to reduce microbial degradation of the samples. By increasing the salinity of the preservative a stable layer (density gradient) is created at the bottom of the collection cylinders. This layer tends to hold particulates at the bottom of the cylinders and reduce the rate at which the preservative is lost. Prior to deployment, the collection cylinders were cleaned with sequential washes of hot tap water/Liquinox® detergent, 10 percent nitric acid, distilled/deionized water, and pesticide grade acetone, then air-dried and wrapped in aluminum foil until used in the field.

Upon retrieval of the traps, overlying water in the collection cylinders was removed with a peristaltic pump. The remaining contents were then transferred to half-gallon priority pollutant-cleaned glass jars with teflon-lined lids (supplied by I-Chem, Hayward, CA) and stored at 4°C for transport to the laboratory, where they were frozen within 12 hours of collection pending processing. Processing consisted of first thawing the samples and then centrifuging to isolate the particulate fraction. All nekton >2 cm in size were removed from the samples. In order to obtain sufficient volume for organics analyses, SPM samples from two consecutive collection periods (*i.e.*, semi-annually) were composited. All other analyses were conducted on a quarterly basis. Manipulation of all SPM samples in the laboratory was accomplished with stainless steel spoons cleaned as previously described for the collection cylinders.

Bottom Sediment Sampling

Sampling procedures followed Puget Sound Protocols where applicable (Tetra Tech, 1986). Surface sediments were collected at each of the sediment trap locations on two occasions using a 0.1 m^2 stainless steel van Veen grab. Samples for metals, semivolatile organics, and butyltins determinations were collected on December 5, 1989. A second collection for butyltins analysis was also conducted on January 24, 1991.

To assess environmental variability for the various chemical groups, replicate samples (*i.e.*, two separate samples from the same location) were collected at stations TF-1 (head) and TF-4 (mouth). Blind field duplicates (*i.e.*, two samples split from the same homogenate) were also prepared to assess overall variability (sample collection + laboratory analysis).

After retrieving the grab, the top 2 cm layer not in contact with the sidewalls of the sampler was transferred to a stainless steel beaker and homogenized by stirring with a stainless steel spoon. Aliquots for individual analyses were taken from this homogenate and placed in priority-pollutant cleaned glass jars with teflon-lined lids supplied by I-Chem Hayward, CA, wrapped in polyethylene bags, and stored at 4°C for transport to the laboratory. Spoons and beakers were pre-cleaned as previously described for the sediment trap collection cylinders.

Analysis and Quality Assurance

The chemical analyses, analytical methods, and laboratories used in this study are listed in Table 3. Quality of the data sets were assessed by analysis of method blanks, internal standards, surrogate spikes, duplicate matrix spikes, blind field duplicates and standard reference materials (SRMs).

Results of metals analysis of two marine sediment SRMs are shown in Table 4. Acceptable accuracy was obtained for all metals being within $\pm 10\%$ of the certified range. Two exceptions were cadmium (14%, PACS-1 only) between May - November 1992 and mercury (12% - November 1991 to May 1992 and 20% - May 1992 to November 1992, NIST 1646 only) between November 1991 - November 1992 period. For the May - November 1992 period the laboratory reported that NIST - 1646 had potentially been contaminated for mercury. As a result, one additional low level marine sediment reference material was analyzed for mercury (BEST-1- National Research Council of Canada). Acceptable accuracy was obtained with BEST-1- for mercury being within $\pm 10\%$ of the certified range. Assuming the average of these two reference materials suggests that mercury values could be 10% high for the May - November 1992 collection period. Based on the results from analysis of the reference materials indicated both cadmium and mercury results for the affected periods have been qualified as estimates, since they probably overestimate actual environmental levels by approximately 10%.

Beginning with the June to November 1991 monitoring period, a Canadian reference material for polynuclear aromatic hydrocarbons (PAH) in marine sediment was analyzed concurrently

Table 3: Summary of analytical methods for Thea Foss Waterway sediment trap monitoring project, June 1989 to November 1992.

Analysis	Method	Reference	Laboratory
		SETTLING PARTICULATE MATTER/SEDIMENT	
Percent Solids	Dry @ 104°C	Tetra Tech, 1986	Ecology/EPA-Manchester, WA.
Total Organic Carbon	Combustion/CO2 Measurement	" "	Analytical Resources, Inc.-Seattle, WA.
			Laucks Laboratories- Seattle, WA.
			AMTEST-Redmond, WA.
			Sound Analytical Services, Inc.-Tacoma, WA.
Grain Size	Seive and Pipet	Holme and McIntrye, 1971	Laucks Laboratories- Seattle, WA.
			Soil Technology, Inc.-Winslow, WA.
Metals			
Copper,Nickel,	X-Ray Fluoresence	Nielson and Sanders, 1983	Battelle Northwest-Richland, WA.
Lead,Zinc			
Cadmium	GFAA	Tetra Tech, 1986	Battelle Northwest-Sequim, WA.
Mercury	CVAA	" "	" " "
Organics			
Semivolatiles	GC/MS #1625C (6-12/89)	EPA, 1989b	Analytical Resources, Inc.- Seattle, WA./
	GC/MS #8270 (1/90-11/92)	EPA, 1986	Ecology/EPA-Manchester, WA.
Butyltins	GC/FPD	Tetra Tech, 1986	" " "
		WATER	
Total Suspended Solids	Gravimetric #205C	APHA, 1985	Ecology/EPA-Manchester, WA.
Temperature/Salinity	Seacat SBE19-CTD	Seabird Electronics	Field
Current Velocity	Aanderaa Current Meter	Aanderaa Instruments	Field
	Model RCM-4		

Table 4: Results of analysis of certified reference materials for metals in marine sediment (mg/kg, dry).

I. High Level

Material		PACS-1							
	Certified	Battelle Result							
Date	Range	6-12/89	1-6/90	7-12/90	1/91	1-6/91*	6-11/91*	11/91-5/92*	5-11/92*
Cadmium	2.36-2.40	2.49	-	-	2.50	2.60	2.52	2.38	2.73
Copper	436-468	407	-	-	441	405	411	425	447
Lead	384-424	394	-	-	438	403	403	410	397
Mercury	4.41-4.73	4.42	-	-	4.69	4.88	4.60	4.92	-
Nickel	42.1-46.1	50.7	-	-	49.3	45.3	43.9	42.8	45.3
Zinc	802-846	761	-	-	774	804	799	786	817

II. Low Level

Material		NIST-1646							
	Certified	Battelle Result							
Date	Range	6-12/89	1-6/90+	7-12/90+	1/91	1-6/91*	6-11/91*	11/91-5/92*	5-11/92*
Cadmium	0.29-0.43	0.29	0.36	0.39	0.40	0.40	0.37	0.44	0.42
Copper	15-21	20.9	20.0	15.8	20.9	20.8	20.3	20.6	21.9
Lead	26.4-30.0	28.9	27.4	29.1	30.7	29.0	29.1	29.1	29.1
Mercury	0.051-0.075	0.06	0.071	0.074	0.074	0.050	0.061	0.084	0.09
Nickel	29.0-35.0	35.4	32.7	34.4	36.6	33.1	31.7	32.5	31.4
Zinc	132-144	123	138	128	138	140	132	135	135

PACS-1=Trace Metals in Marine Sediment (National Research Council of Canada)

NIST-1646=Estuarine Sediment (National Institute of Standards and Technology)

+=Reported as mean of duplicate analysis

*=Reported as mean of triplicate analysis

-=Not analyzed

=Outside certified range by more than 10%

with the samples for semivolatiles organics determinations. Results of these analyses are shown in Table 5. The majority of compounds had acceptable accuracy being within ±20% of the certified range. Results for compounds that fell outside ±20% of the certified range have been qualified as estimates when reported. Based on analysis of the Canadian reference material, the affected values for PAHs are conservative and could underestimate actual environmental levels by a factor of two or less.

Estimates of overall precision (sample collection + laboratory analysis) calculated as relative percent difference (RPD: range as a percent of the mean) using detected compounds in blind field duplicates were as follows:

- SPM: Conventionals (≤10%); metals (≤15%); semivolatile organics (low molecular weight PAH (LPAH) ≤43%, high molecular weight PAH (HPAH) ≤57%, phenols 88%, and phthalates ≤63%); and butyltins (≤46%)

- Bottom sediment: Conventionals (≤10% except total organic carbon (TOC) ≤19%); metals (≤15%); semivolatile organics (LPAH 13%, HPAH 9%, phenols na, and phthalates 11%); and butyltins (28%).

Results of analyses of blind field duplicates are summarized in Appendix B- Table B1 (metals) and Table B2 (organics). These data indicate that sample handling procedures and laboratory analyses were not major contributors to data variability for most analytes. The highest variability was associated with semivolatile organics analysis of SPM where concentrations could vary by up to a factor of two.

Quality assurance review of the semivolatile organics data was performed by Dickey Huntamer of the Ecology/EPA Manchester Laboratory. The data were reviewed for qualitative and quantitative accuracy, validity, and usefulness. This included an evaluation of sample holding times, method blanks, surrogate recoveries, and matrix spike duplicate results. The major analytical problem encountered in the analysis of these samples, was higher quantitation limits on SPM samples analyzed in 1991. Overall the data is considered acceptable for use, with the accompanying qualifiers noted where appropriate.

SPM samples in 1991 were pre-screened by Gas Chromatography/Flame Ionization Detection (GC/FID) prior to analysis. Samples which had a high hydrocarbon/lipid background were diluted, which resulted in higher quantitation limits for these samples. Case narratives and data reviews for the organics analyses are included in Appendix B.

Quality assurance review of the butyltin analyses was performed by Keith Solberg and Dickey Huntamer of the Ecology/EPA Manchester Laboratory. Again the data were reviewed for qualitative and quantitative accuracy, validity, and usefulness; by evaluating sample holding times, method blanks, surrogate recoveries, and matrix spike duplicate results. The major analytical problem encountered in the butyltin analysis was interferences caused by most of the samples having a high sulfur content in the extracts. Sulfur was

Table 5: Result of analysis of certified reference materials for polynuclear aromatic hydrocarbons (PAH) in marine sediment (ug/kg, dry).

Standard	HS-6			Certified
Collection Period	6-11/91+	12/91-5/92*	5-11/92*	Range
Napthalene	3100	1500	3100	3000-5200
Acenaphthylene	280	190 j	350	140-240
Acenapthene	130	97 j	120	160-300
Flourene	320	300	290	350-590
Phenanthrene	2600	2700	2800	2400-3600
Anthracene	680	640	760	700-1500
Flouranthene	2700	2600	3000	2890-4190
Pyrene	2700	2600	2200	2400-3600
Benzo(a)athracene	1700	1400	1400	1500-2100
Chrysene	1800	1900	2000	1700-2300
Benzo(a)pyrene	1700	950	1200	1800-2600
Benzo(b)flouranthene	5100	3100	2300	2400-3400
Benzo(k)flouranthene	560	830	1900	1280-1580
Benzo(g,h,i)perylene	1600	590	440	1060-2500
Dibenzo(a,h)anthracene	670	310	410	330-650
Indeno(1,2,3-cd)pyrene	1700	940	1500	1370-2530

+=Reported as mean of quadruplicate analysis

*=Reported as mean of duplicate analysis

j=Estimated concentration

HS-6= PAH in Marine Sediment- National Research Council of Canada

=Exceeds certified range by more than 20%

removed from the samples by treatment with elemental mercury prior to derivitization (hexylation) with Grignard reagent. This treatment was not 100% effective in all cases. Consequently, the reported concentrations probably underestimate actual environmental levels based on examination of spike recovery data. Case narratives and data reviews for the butyltin analyses are included in Appendix B.

Unless otherwise noted, all concentrations in this document are reported on a dry weight basis.

RESULTS

Water Column

Vertical profiles of temperature, salinity and light transmittance collected during deployment and retrieval of the sediment traps, at two mid-channel stations (Figure 1), between October 1990 and November 1991 are shown in Figure 2. In general, similar profiles were noted at both stations during concurrent periods. In the majority of profiles (especially March) there was evidence of a freshwater layer at the surface. In addition, light transmittance data indicated that a turbid bottom layer was also present in approximately one-half of the profiles. TSS concentration, shown in Appendix C- Table C1, were similar at both water column stations ranging from 1-15 mg/L.

Current Velocity

Current velocity distributions for three locations in Thea Foss Waterway are presented in Figure 3. Velocities in the waterway ranged from 2-28 cm/sec. The minimum value represents the lower limit of detection for the instrument. Examination of Figure 3 indicates that current velocities are generally slow throughout the waterway (geo. mean head= 2 cm/sec, middle= 2.3 cm/sec, and mouth= 2.7 cm/sec) during deployment of the meters (spring tidal series). The lowest velocities were measured at the head of the waterway where currents are $\leq$4 cm/sec 90% of the time. This result implies that poor flushing characteristics are present at the head of the waterway. Velocities in the central and outer portion of the waterway during June of 1989 were $\leq$4 cm/sec 77% and 69% of the time, respectively. For comparison, velocities measured in other Commencement Bay waterways between December 27, 1990, and February 5, 1991, were as follows: Hylebos 2-85 cm/sec, Geo. mean= 5.5 cm/sec; Sitcum 2-150 cm/sec, Geo. mean= 3.4 cm/sec.

SPM

Out of 56 sediment traps deployed in Thea Foss Waterway between June 1989 and November 1992, 44 were successfully recovered (79%). However, since June of 1991 the recovery rate has been >90%. The majority of the earlier losses are attributed to vessel activity in the waterway and equipment failures.

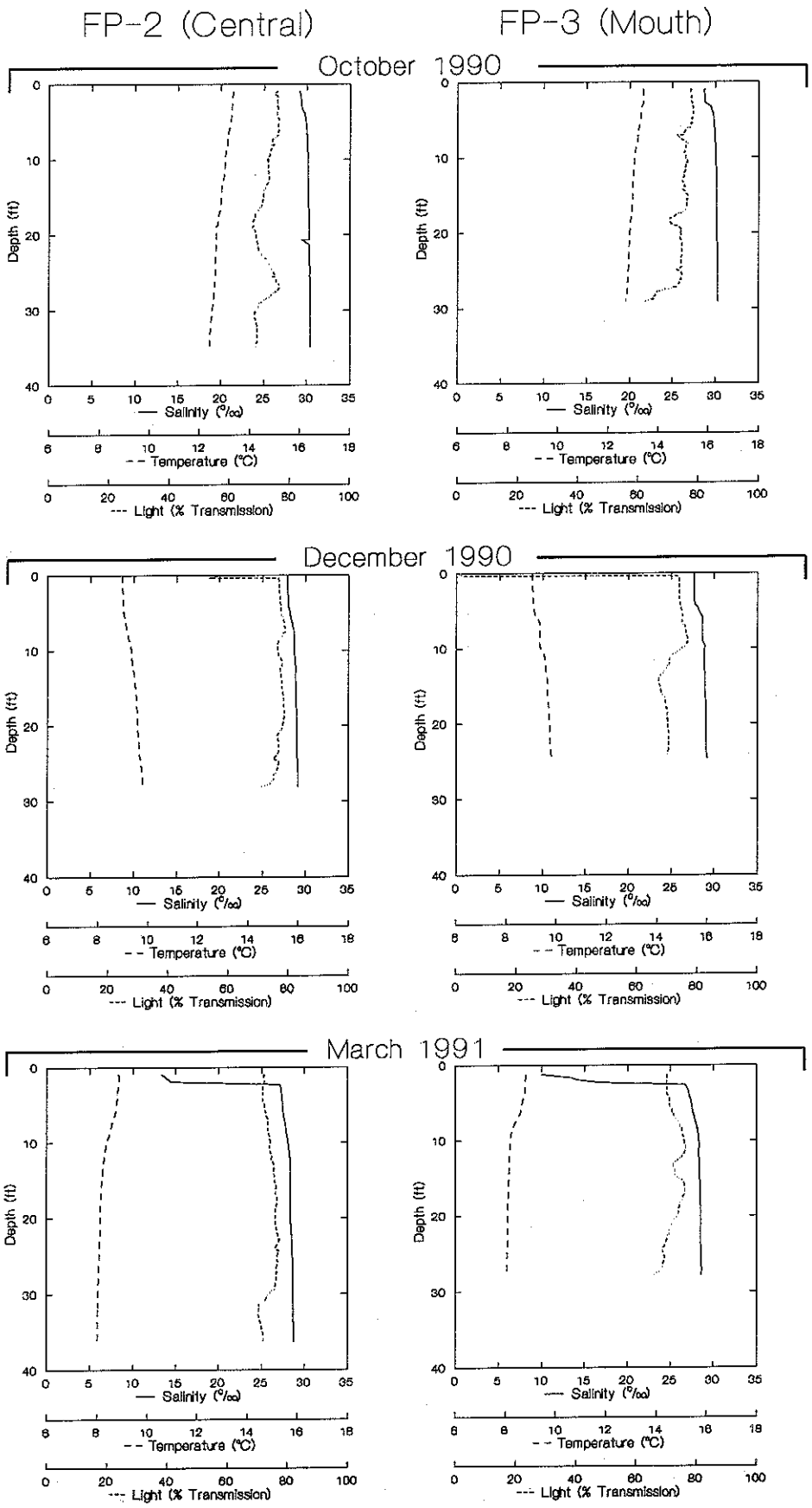

Figure 2: Temperature, salinity, and light transmittance profiles for Thea Foss Waterway October 1990 to November 1991.

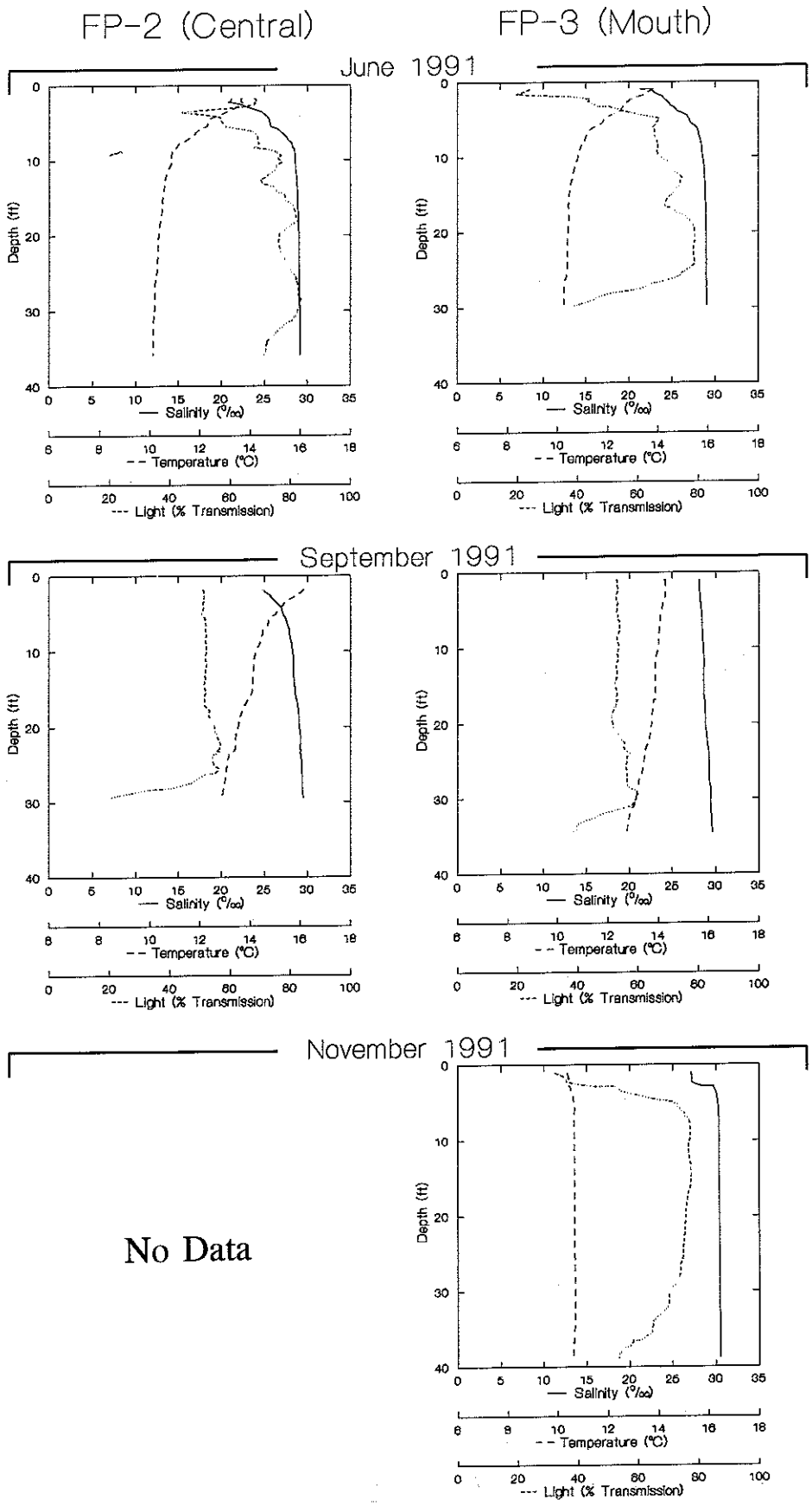

Figure 2 (continued): Temperature, salinity, and light transmittance profiles for Thea Foss Waterway October 1990 to November 1991.

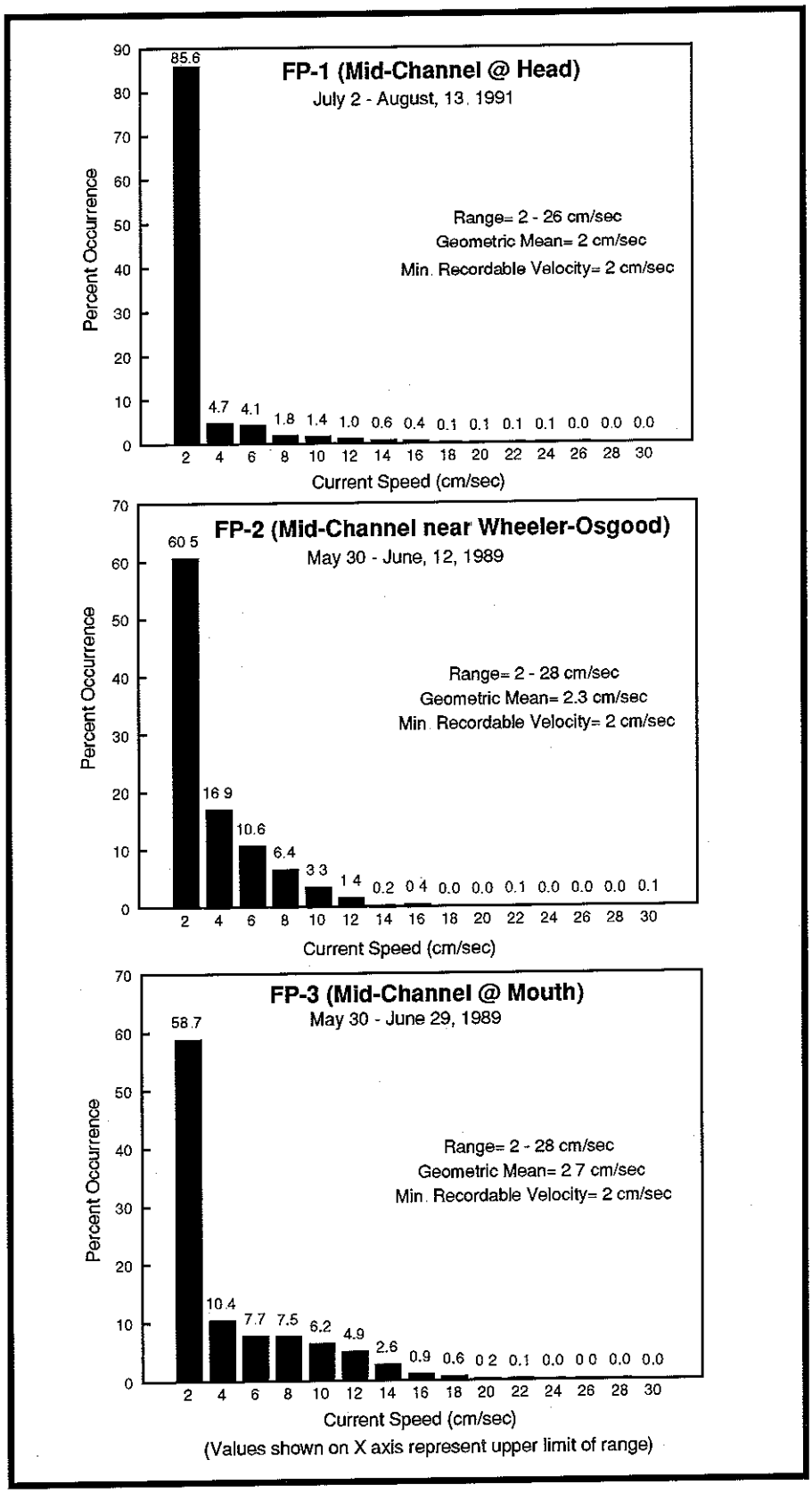

Figure 3: Current velocity distributions for Thea Foss Waterway.

The results of conventionals [total solids (TS), and TOC], and metals analyses of SPM samples from Thea Foss Waterway collected between June 1989 and November 1992 are presented in Table 6.

TS concentrations (post-centrifugation) measured over the collection period ranged from 4.2 to 48.2%. TOC concentration ranged from 1.9 to 11%. Relatively high concentrations of TOC were present in Foss Waterway, especially at the head. The mean concentration at the head (8.1%) was elevated by almost a factor of two compared to the mean at the mouth (4.5%) at the waterway. TOC was identified as a "problem" chemical (see introduction) at the head of the waterway during the CB/NT RI.

Concentrations of "problem" metals in Thea Foss Waterway SPM reported in mg/kg were as follows:

Metal	Range	Mean	C.V.	N
• Cadmium	0.8 - 3.7	2.2	0.33	44
• Copper	120 - 340	190	0.26	44
• Lead	120 - 400	250	0.35	44
• Mercury	0.35 - 1.0	0.63	0.26	44
• Nickel	28 - 81	44	0.31	44
• Zinc	160 - 490	300	0.31	44

For all metals at least one station varied significantly among sites (ANOVA; $P<0.001$). Peak concentrations of cadmium, lead, nickel, and zinc were measured at the head of Foss Waterway near the twin 96" drains. The highest copper concentrations were present near the mouth of Wheeler-Osgood Waterway. On average, mercury levels were at a maximum in the central portion of the waterway near the 15th Street drain and the mouth of Wheeler-Osgood Waterway. The lowest metals concentrations were consistently measured at the mouth of the waterway.

Two longitudinal patterns were evident for metals concentrations in Foss Waterway. Cadmium, lead, nickel, and zinc showed significant reductions (ANOVA $P<0.001$) moving out the waterway, with the highest concentrations occurring at the head and the lowest at the mouth. In contrast, copper and mercury increased moving away from the head, peaking in the middle, and then decreasing to a minimum at the mouth of the waterway. It should be noted that in seven of eight concurrent samples collected from opposite sides of the waterway at stations TF-2 (15th Street) and TF-3 (mouth of Wheeler-Osgood) copper was higher at TF-3. This would suggest a source of copper is located in or near the mouth of Wheeler-

Table 6: Results of conventionals and metals analysis of settling particulate matter from Thea Foss Waterway collected June 1989 to November 1992.

Location	Head near twin 96" Drains													
Station No.	TF-1													
Sample No.	8093/ 8128*	8094/ 95*	8105/ 07*	-	8112/13/ 23+	8287/88/ 8311+	8304/ 05*	-	-	8569	8400/ 01*	8415	8308/ 09*	8320
Collection Period	5-8/89	8-12/89	1-4/90	4-6/90	7-10/90	10-12/90	12/90-3/91	4-6/91	6-9/91	9-11/91	11/91-2/92	2-5/92	5-8/92	8-11/92
Total Solids %	29.0	4.2	39.0	-	36.0	45.5	45.9	-	-	35.0	42.0	39.0	38.0	40.0
TOC %	6.6	11	7.9	-	10.1	9.1	7.6	-	-	6.3	6.8	6.3	8.6	9.2
Metals (mg/kg, dry)														
Cadmium	2.9	1.9	2.5	-	3.1	2.3	2.3	-	-	3.1	2.7	2.6	3.6 j	3.7 j
Copper	180	120	140	-	190	150	150	-	-	210	150	160	200	210
Mercury	0.66	0.40	0.51	-	0.63	0.50	0.55	-	-	0.72	0.79 j	0.57 j	0.76 j	0.68 j
Nickel	64	71	81	-	63	80	69	-	-	56	62	54	47	63
Lead	370	330	360	-	350	360	400	-	-	380	370	350	340	390
Zinc	370	410	410	-	340	400	460	-	-	460	460	410	380	490

Location	North of 15th Street Drain													
Station No.	TF-2													
Sample No.	-	-	-	-	8306	8297	-	8313	8502	8515	8404	8419/ 20*	8313/ 14*	8323
Collection Period	5-8/89	8-12/89	1-4/90	4-6/90	7-10/90	10-12/90	12/90-3/91	4-6/91	6-9/91	9-11/91	11/91-2/92	2-5/92	5-8/92	8-11/92
Total Solids %	-	-	-	-	28.0	36.6	-	32.9	36.8	39.1	44.0	35.0	41.0	39.0
TOC %	-	-	-	-	9.6	6.1	-	2.3	4.7	4.7	5.1	4.8	6.5	5.1
Metals (mg/kg, dry)														
Cadmium		-	-	-	2.1	1.9	-	2.1	2.4	2.8	2.3	2.6	3.1 j	1.5 j
Copper	-	-	-	-	160	180	-	230	180	240	170	170	200	190
Mercury	-	-	-		0.61	0.64	-	0.74	0.63	0.90	0.89 j	0.78 j	0.88 j	0.96 j
Nickel	-		-	-	37	40	-	38	36	35	40	41	36	39
Lead	-	-	-	-	240	240	-	270	240	260	260	280	270	290
Zinc	-	-	-	-	270	260	-	270	260	290	260	280	300	240

*=Reported as mean of two samples
+=Reported as mean of three samples
-=No sample (sediment trap was not recovered)
j=Estimated Concentration

Table 6 (continued): Results of conventionals and metals analysis of settling particulate matter from Thea Foss Waterway collected June 1989 to November 1992.

Location	Mouth of Wheeler-Osgood Waterway													
Station No.	TF-3													
Sample No.	8098	8099	8106/ 08*	8117	8307	8298	-	8314/ 15*	8503/ 04*	8516/ 19*	8408	8421/ 22*	-	8324/ 25*
Collection Period	5-8/89	8-12/89	1-4/90	4-6/90	7-10/90	10-12/90	12/90-3/91	4-6/91	6-9/91	9-11/91	11/91-2/92	2-5/92	5-8/92	8-11/92
Total Solids %	30.0	18.9	38.0	33.0	41.0	42.3	-	36.5	39.0	46.4	41.0	37.0	-	43.0
TOC %	5.6	6.5	5.5	NA	8.1	5.3	-	2.1	4.7	5.3	4.1	5.5	-	5.7
Metals (mg/kg, dry)														
Cadmium	2.6	2.4	2.0	2.6	3.0	2.3	-	2.2	2.4	3.1	2.2	2.9	-	3.0 j
Copper	210	220	340	210	270	250	-	180	220	311	190	230	-	230
Mercury	0.69	0.61	0.68	0.79	0.72	0.65	-	0.67	0.6	0.79	0.71 j	1.0 j	-	0.70 j
Nickel	46	42	43	40	36	41	-	36	33	39	38	38	-	35
Lead	250	240	230	250	250	240	-	240	220	270	210	270	-	220
Zinc	300	320	440	340	360	350	-	280	290	410	270	340	-	310

Location	Mouth near D-Street Tank Farms													
Station No.	TF-4													
Sample No.	8102/ 06*	-	8110/ 09*	-	8308/ 09*	8299/ 8300*	8308	8319/ 8326*	8508/ 09*	8522	8412	8425	8317	8329/ 30*
Collection Period	5-8/89	8-12/89	1-4/90	4-6/90	7-10/90	10-12/90	12/90-3/91	4-6/91	6-9/91	9-11/91	11/91-2/92	2-5/92	5-8/92	8-11/92
Total Solids %	30.0	-	33.8	-	36.0	48.2	40.3	31.3	29.3	39.6	44.0	33.0	37.0	43.0
TOC %	5.0	-	5.4	-	4.8	3.6	2.1	1.9	4.8	4.3	7.3	4.5	5.3	4.6
Metals (mg/kg, dry)														
Cadmium	1.4	-	0.9	-	1.4	0.8	0.9	1.4	1.9	1.3	1.3	1.3	1.7 j	1.5 j
Copper	120	-	140	-	150	130	160	160	130	190	120	130	150	150
Mercury	0.42	-	0.38		0.48	0.36	0.45	0.48	0.35	0.59	0.49 j	0.44 j	0.44 j	0.41 j
Nickel	35	-	39	-	33	33	37	33	28	32	35	33	31	31
Lead	120	-	130	-	160	120	180	160	120	120	120	150	130	130
Zinc	170	-	220	-	200	170	280	210	160	170	180	200	200	180

*=Reported as mean of two samples

+=Reported as mean of three samples

-=No sample (sediment trap was not recovered)

j=Estimated Concentration

Osgood Waterway. Previous studies have documented high concentrations of copper in sediments at J.M. Martinac Shipbuilding (Norton and Johnson, 1984). Sources of copper at Martinac Shipbuilding include; the use of granulated slag as sandblasting material, and removal of antifouling paints during vessel renovations (Tetra Tech, 1985). Temporally, intra-station metals concentrations were quite similar, being within a factor of two.

Summarized in Table 7 are the results of semivolatile organics and butyltins analyses of SPM from Thea Foss Waterway. Thirty-one target semivolatile organic compounds were detected in SPM. Detected concentrations of "problem" organics in SPM reported in ug/kg ranged as follows:

Chemical	Range	Mean	C.V.	N
• LPAH	250-32000	6700	1.1	24
• HPAH	980-120000	27000	1.0	23
• Phenol	68-4400	970	1.5	8
• 4-Methyl phenol	110-3700	1100	1.3	9
• Butyl benzyl phthalate	290-3600	1200	0.88	9
• Bis (2-ethyl hexyl) phthalate	2200-45000	11000	1.0	15
• Benzyl alcohol	67-85	76	0.12	3

On average, concentrations of most semivolatile compounds tended to be highest at the head of the waterway. In particular, HPAH concentrations were significantly higher (ANOVA; $P<0.001$) at the head of the waterway. The lowest concentrations of most problem chemicals were typically measured at the mouth of the waterway.

In contrast to metals, few strong longitudinal gradients were evident for semivolatile organics in Foss Waterway, with the exception of HPAH. HPAH concentrations were highest at the head and decreased moving toward the mouth of the waterway. Major PAH sources previously identified at the head of Foss Waterway included; discharge from storm drains-primarily the twin 96", and operation of a historic coal gasification plant (Tetra Tech, 1985).

Temporally, intra-station concentrations of most "problem" chemicals tended to be somewhat variable, ranging within an order of magnitude. However, differences in quantitation limits between several of the monitoring periods hinder interpretations of temporal trends (see quality assurance section).

Table 7:Summary of semivolatile organics and butyltin analysis of settling particulate matter from Thea Foss Waterway collected June 1989 to November 1992 (ug/kg, dry).

Location	Head near Twin 96" Drains TF-1							North of 15th Street Drain TF-2						
Station No.	8096/					8426/	8331/							
Sample No.	97*	8118	8301	8320	8569	27*	32*	-	-	8302	8313	8524	8428	8333
Collection Period	5-12/89	1-6/90	7-12/90	1-6/91	6-11/91	12/91-5/92	5-11/92	5-12/89	1-6/90	7-12/90	1-6/91	6-11/91	12/91-5/92	5-11/92
Total Organic Carbon (%)	9.5	7.9	8.6	2.6	6.3	6.6	8.7	-	-	7.9	2.3	4.7	4.9	6.0
Semivolatiles														
Acenaphthene	370 j	850	220 j	980 j	62 j	390 j	220 j	-	-	470 u	8200 u	50 j	280	190 j
Acenaphthylene	370 j	300 u	360 u	8500 u	140 u	310 j	200 j	-	-	470 u	8200 u	970 u	300	200 j
Naphthalene	380 u	510	200 j	850 j	92 j	420 j	430	-	-	470 u	8200 u	130 j	620	440
Fluorene	610 j	1400	410	1500 j	100 j	780 j	330	-	-	230 j	8200 u	74 j	460	240
Anthracene	1300	3400	740	2600 j	96 j	310 u	880	-	-	430 j	8200 u	970 u	700	530
Phenanthrene	7100	16000	4100	26000	1500	8800 j	3700	-	-	1800	8200 u	970 u	2800	1200
Sum LPAH	9800 j	22000	5700 j	32000 j	1800 j	11000 j	5800 j	-	-	2500 j	-	250 j	5200	2800 j
Fluoranthene	14000	17000	8000	28000	3000	9100 j	8200	-	-	3400	8200 u	970 u	3800	2200
Benzo(a)anthracene	4900	6100	2700	12000	1600	10000	2200	-	-	1000	8200 u	970 u	4100 u	830
Chrysene	6300	11000	4500	15000	960	12000	5300	-	-	1700	8200 u	970 u	4400	1500
Pyrene	12000	16000	6300	33000	3000	10000	7100	-	-	2300	8200 u	970 u	3300	2800
Benzofluoranthenes	12000	16000	7500	15000 j	2600 j	15000 j	7200	-	-	2600	8200 u	970 u	3500 j	2400
Benzo(a)pyrene	4800	5100	2900	7400 j	1100	5600 j	3100 j	-	-	910 j	8200 u	970 u	260 u	1000 j
Dibenzo(a,h)anthracene	2400	1300	740 j	22000 u	360 u	780 u	730	-	-	290 j	21000 u	2500 u	670 u	190
Indeno(1,2,3-cd)pyrene	2100	3600	2400	6100 j	1100	310 u	2800	-	-	1100 j	8200 u	970 u	260 u	180 j
Benzo(g,h,i)perylene	2100 j	410	610	5900 j	930	310 u	1500 j	-	-	470 u	8200 u	970 u	260 u	590 j
Sum HPAH	61000 j	77000	36000 j	120000 j	14000 j	62000 j	38000 j	-	-	13000 j	-	-	15000 j	12000 j
Total PAH	71000 j	99000	42000 j	150000 j	16000 j	73000 j	44000 j	-	-	16000 j	-	250	20000 j	15000 j
Phenol	460 j	600 u	720 u	8500 u	140 u	1300	210 u	-	-	950 u	8200 u	970	260 u	140 u
Pentachlorophenol	750 u	500	1800 u	44000 u	na	1600 uj	210 u	-	-	2400 u	42000 u	nar	nar	140 u
4-methylphenol	3100	300 u	360 u	8500 u	140 u	310 u	120 j	-	-	470 u	8200 u	970 u	260 u	110 j
1-methylnaphthalene	na	na	na	650 j	70 j	330 j	220 j	-	-	na	8200 u	54 j	280	180
2-methylnaphthalene	360 j	380	360 u	610 j	69 j	290 j	220 j	-	-	470 u	8200 u	34 j	260 j	160 j
Carbazole	2400	-	-	17000 j	730 uj	3600 j	690	-	-	-	42000 u	5000 uj	1400 uj	120 j
Benzoic Acid	3800 u	6200	2100 j	9400 j	1100 j	46000 j	6500	-	-	7400	110000 u	970 uj	3400 uj	3700
Benzyl Alcohol	1900 u	1500 u	1800 u	na	730 u	1600 u	67 j	-	-	2400 u	na	5000 uj	1400 u	77 j
Retene	na	na	na	3900 u	140 u	310 u	480	-	-	na	8200 u	970 u	260 u	440
Dibenzofuran	300 j	900	250 j	1100 j	73 j	440 j	260	-	-	470 u	8200 u	970 u	300	220
Diethyl phthalate	420 j	300 u	360 u	8500 u	140 u	310 u	210 u	-	-	470 u	8200 u	970 u	260 u	140 u
Dimethyl phthalate	360 j	300 u	360 u	8500 u	140 u	570 j	210 u	-	-	470 u	8200 u	970 u	260 u	140 u
Butyl benzyl phthalate	3600	300 u	1600	8500 u	360 u	780 u	1200 j	-	-	470 u	21000 u	2500 u	670 u	290
Di-n-butyl phthalate	380 u	400	360 u	8500 u	140 u	7000 j	420 u	-	-	470 u	8200 u	970 u	2000 u	140 u
Di-n-octyl phthalate	720 j	2100	360 u	8500 uj	140 uj	310 uj	510 uj	-	-	470 u	8200 uj	970 uj	260 uj	350 u
Bis(2-ethylhexyl)phthalate	18000	16000	11000	54000 u	4700 u	18000	11000	-	-	5300	8200 u	1600 u	4600 u	45000 j
Butyltins														
Monobutyltin	73 u	76	23 j	3.5 u	na	53 j	140 uj	-	-	82 u	na	72	43 u	200 uj
Dibutyltin	200	42 j	58	5.9	na	160 j	140 uj	-	-	56	na	73	48 u	200 uj
Tributyltin	450	73	140	11	na	480 j	160	-	-	190	na	48	300 j	150 j
Tetrabutyltin	88 u	51 u	47 u	2 u	na	74 j	140 uj	-	-	98 u	na	61 u	55 j	200 uj

*=Reported as mean of duplicates
+=Reported as mean of three samples
u=Not detected at detection limit shown
nar=No analytical result
j=Estimated concentration
=Problem chemical
na=Not analyzed
-=No sample

Table 7 (continued):Summary of semivolatile organics and butyltin analysis of settling particulate matter from Thea Foss Waterway collected June 1989 to November 1992 (ug/kg, dry).

Location	Mouth of Wheeler-Osgood Waterway							Mouth near D-Street Tank Farms						
Station No.	TF-3							TF-4						
Sample No.	8101	8108/ 8117/11+	8303	8322/ 27*	8525/ 26*	8429	8334	8105	8119	8304/ 05*	-	8527	8430	8335
Collection Period	5-12/89	1-6/90	7-12/90	1-6/91	6-11/91	12/91-5/92	5-11/92	5-12/89	1-6/90	7-12/90	1-6/91	6-11/91	12/91-5/92	5-11/92
Total Organic Carbon (%)	6.1	5.8	6.8	2.1	5.0	5.0	5.7	5.0	5.4	4.4	-	4.6	5.9	4.8
Semivolatiles														
Acenaphthene	700	430 j	450	1600 j	98 j	670	290 j	220 j	140 u	510 u	-	31 j	160 j	260 j
Acenaphthylene	210 j	240 j	270 u	300 j	130 j	320	310 j	380	140 u	510 u	-	37 j	220	220 j
Naphthalene	390 j	440	280 j	3600 j	210 j	840	620	260 j	440	250 j	-	87 j	290	380
Fluorene	590	900	390	1600 j	130 j	520	330	330 j	460	290 j	-	44 j	240	320
Anthracene	840	1600	630	7400 u	170 j	140 u	700	1200	1400	490 j	-	42 j	390	540
Phenanthrene	2400	4700	2300	6600 j	670 j	3200	1600	2100	2900	2000	-	390	2000	1400
Sum LPAH	5100 j	8200 j	3800 j	14000 j	1400 j	5600	3900 j	4500 j	5200	3000 j	-	630 j	3300 j	3100 j
Fluoranthene	4000	3900	3200	4400 j	1200 j	3200	3400	3100	4400	3900	-	490 j	2600	2300
Benzo(a)anthracene	1600	1300	1400	7400 u	420 j	3000 u	1300	1700	1300	1200	-	290	2300 u	890
Chrysene	2200	2800	2200	2500 j	540 j	3200	2100	2000	2500	1900	-	200	2600	1500
Pyrene	4400	3800	2800	6300 j	1100 j	4200	4100	4300	2900	2900	-	340	2100	2600
Benzofluoranthenes	3700	3700	3400	1800 j	990 j	4700 j	3300	3800	3400	2900	-	340 u	2200 j	2000
Benzo(a)pyrene	1600	1200	1300	1300 j	400 j	1300 j	1500 j	2200	940	1300 j	-	150	170 u	930 j
Dibenzo(a,h)anthracene	370 j	330	280 j	18000 u	390 j	360 u	160	460	190	410 j	-	150 u	420 u	200 u
Indeno(1,2,3-cd)pyrene	970	750	970	7400 u	460 j	140 u	1200	1000	530	1000 j	-	60 u	170 u	770
Benzo(g,h,i)perylene	1000	250 u	220 j	7400 u	410	140 u	900 j	990	140 u	470 j	-	60 u	170 u	510 j
Sum HPAH	20000 j	18000	16000 j	16000 j	5900 j	17000 j	18000 j	18000	16000	16000 j	-	980 j	9500 j	12000 j
Total PAH	25000 j	26000 j	20000 j	30000 j	7300 j	23000 j	22000 j	23000 j	21000	19000 j	-	1600 j	13000 j	15000 j
Phenol	170 j	540 u	400 u	4400 j	89 u	340 u	200 u	68 j	200	1000 u	-	210	170 u	200 u
Pentachlorophenol	340 u	1400 u	980 u	38000 u	450 u	nar	200 u	1300	270	2600 u	-	310 u	nar	200 u
4-methylphenol	170 u	270 u	550	7400 u	350 j	140 u	190 j	3700	140 u	510 u	-	1700 j	170 u	210
1-methylnaphthalene	na	na	na	1200 j	84 j	410	220	na	na	na	-	42 j	170	200
2-methylnaphthalene	240 j	320 j	210 j	1100 j	81 j	350	230	110 j	200	580 u	-	42 j	150 j	200 j
Carbazole	990	-	-	7400 u	460 uj	730 uj	180 j	570	-	-	-	310 uj	860 uj	170 j
Benzoic Acid	1700 u	7900	700 j	12000 j	870 j	6500 j	450 u	1400 u	9700	3200 j	-	860 j	7300 j	5400
Benzyl Alcohol	860 u	1400 u	980 u	na	460 uj	730 u	200 u	690 u	710 u	2600 u	-	310 u	860 u	85 j
Retene	na	na	na	2700 u	140 j	140 u	550	na	na	na	-	60 u	170 u	490
Dibenzofuran	350 j	480 j	280	1300 j	95 j	400	310	120 j	300	510 u	-	33 j	160 j	250
Diethyl phthalate	130 j	270 u	200 u	7400 u	89 u	140 u	200 u	100 j	140 u	510 u	-	60 u	170 u	200 u
Dimethyl phthalate	170 u	270 u	200 u	7400 u	89 u	140 u	200 u	140 u	140 u	510 u	-	60 u	170 u	200 u
Butyl benzyl phthalate	310 j	270 u	370 j	18000 u	230 u	360 u	450	970	140 u	510 u	-	150 u	420 u	1600
Di-n-butyl phthalate	170 u	270 u	270 u	7400 u	89 u	3900 u	200 u	140 u	140 u	510 u	-	60 u	170 u	1500 j
Di-n-octyl phthalate	310 j	610 j	200 u	7400 u	89 u	140 uj	500 uj	140 u	590	510 u	-	60 uj	170 uj	500 u
Bis(2-ethylhexyl)phthalate	5800	5000	4100	7400 u	2500 u	4200 u	6200	2200	4500	3400	-	800 u	4200 u	12000
Butyltins														
Monobutyltin	52 u	120 j	74 u	100 u	45 u	100 u	na	33	na	65 u	-	50 u	na	120 uj
Dibutyltin	330	71 j	96	100 u	53	120 j	na	110	na	80 j	-	55 u	na	120 uj
Tributyltin	530	130 j	210	100 u	73	560 j	na	230	na	140 j	-	59 u	na	120 u
Tetrabutyltin	63 u	43 u	90 u	100 u	52 u	190 j	na	56 u	na	71 uj	-	63 u	na	120 uj

*=Reported as mean of duplicates
+=Reported as mean of three samples
u=Not detected at detection limit shown
nar=No analytical result
j=Estimated concentration
=Problem chemical
-=No sample
na=Not analyzed

Several additional compounds, not listed as problem chemicals, were also quantified in SPM. They included; pentachlorophenol, benzoic acid, retene, 1-methyl naphthalene, 2-methyl naphthalene, dibenzofuran, carbazole, and four phthalates esters. All these compounds were present at concentrations <2000 ug/kg, with the exception of benzoic acid, carbazole, and di-n-butyl phthalate. Benzoic acid was detected throughout the waterway at concentrations ranging from 700-46000 ug/kg. Carbazole ranged from 120-17000, while di-n-butyl phthalate levels ranged from 400-7000 ug/kg. As was the case for the target organics, the highest concentrations of these chemicals were typically present at the head of the waterway. Chemically carbazole, 1-methyl naphthalene, 2-methyl naphthalene, and dibenzofuran are closely related to the PAHs. Benzoic acid is a naturally occurring compound that is used as a food preservative, manufacture of alkyl resins, production of phenol, and as a plasticizer to manufacture and modify resins such as PVC (Verschueren, 1983). Phthalates are used extensively as plasticizers and are present in a wide variety of plastic products. In addition, they are also used in the manufacture of non-plastic products such as lubricating oils and insecticides (Tetra Tech, 1986).

Unknown hydrocarbons and a variety of biologically related compounds were also tentatively identified in SPM. Tentatively identified organics are found during mass spectral searches of sample extracts; they represent some of the most prevalent peaks in sample chromatograms that were not among the original target compounds (PSEP, 1988). Unknown hydrocarbons were present throughout the waterway at estimated concentrations ranging from 1500 - 6,000,000 ug/kg. The majority of the biologically derived compounds were fatty acids and sterols. These compounds occur in many marine organisms and are routinely reported in recent estuarine sediments (PSEP, 1988).

Tributyltin (TBT) has been used extensively in the past as an active ingredient in antifouling paints for private and commercial vessels. Tributyltin and its breakdown products, monobutyltin (MBT), and dibutyltin (DBT) were detected in SPM throughout Foss Waterway. Tributyltin concentrations ranged from 11-560 ug/kg with the highest levels occurring near the mouth of Wheeler-Osgood Waterway. The lowest TBT concentrations were present at the mouth of Foss Waterway. Average TBT concentrations in Foss Waterway SPM (230 ug/kg) are approximately one-half of the mean concentration (470 ug/kg) reported in SPM inside two Puget Sound Marinas (Crecelius, *et al.*, 1989).

Sediment accumulation rates for Thea Foss Waterway determined from sediment trap data are shown in Table 8. Two types of accumulation rates are listed. Mass accumulation ($g/cm^2/yr$), which is the measured sediment flux into the traps, and accumulation rate (cm/yr), which is calculated to represent the actual thickness of new sediments once the particulates have consolidated on the bottom. Both these values should be viewed as estimates of gross sedimentation (*i.e.* net sedimentation + resuspension) in the waterway. Calculations used to generate the reported sedimentation rates are shown at the bottom of Table 8.

Table 8: Gross sedimentation rates for Thea Foss Waterway from sediment trap data collected June 1989 to November 1992.

Station Number	Location	Deployment Period	Number Days Deployed	Gross Sedimentation Mass Accumulation (g/cm2/yr)	Gross Sedimentation Accumulation Rate (cm/yr)
TF-1	Head near	6-8/89	89	3.3	6.1
	Twin 96"	8-12/89	96	0.2	0.4
	Drains	1-4/90	96	1.1	2.0
		7-10/90	92	2.7	5.0
		10-12/90	71	2.1	3.9
		12/90-3/91	91	1.5	2.7
		9-11/91	61	0.9	1.6
		11/91-2/92	93	1.1	2.0
		2-5/92	83	1.5	2.7
		5-8/92	91	1.5	2.9
		8-11/92	98	1.2	2.2
			Station Mean	1.6	2.9
			Station Range	(0.2-3.3)	(0.4-6.1)
TF-2	Near 15th	7-10/90	92	0.8	1.3
	Street	10-12/90	71	1.1	2.0
	Drain	4-6/91	49	1.4	2.5
		6-9/91	91	5.0	8.9
		9-11/91	62	1.3	2.3
		11/91-2/92	93	1.2	2.1
		2-5/92	83	0.9	1.6
		5-8/92	90	1.8	3.3
		8-11/92	99	0.8	1.5
			Station Mean	1.6	2.8
			Station Range	(0.8-5.0)	(1.3-8.9)
TF-3	Mouth of	6-8/89	89	3.5	6.5
	Wheeler-	8-12/89	96	1.3	2.4
	Osgood	1-4/90	96	0.7	1.4
	Waterway	4-7/90	75	2.6	4.8
		7-10/90	92	2.5	4.6
		10-12/90	85	1.4	2.7
		3-6/91	81	2.1	3.8
		6-9/91	91	4.1	7.6
		9-11/91	63	3.0	5.6
		11/91-2/92	93	0.8	1.5
		2-5/92	83	0.9	1.2
		8-11/92	98	1.3	2.4
			Station Mean	2.0	3.7
			Station Range	(0.7-4.1)	(1.2-6.5)

Table 8 (continued): Gross sedimentation rates for Thea Foss Waterway from sediment trap data collected June 1989 to November 1992.

Station Number	Location	Deployment Period	Number Days Deployed	Gross Sedimentation: Mass Accumulation (g/cm2/yr)	Gross Sedimentation: Accumulation Rate (cm/yr)
TF-4	Mouth	6-8/89	91	3.9	3.3
	near	1-4/90	96	0.6	0.5
	D-Street	7-10/90	92	1.3	1.0
	Tank Farm	10-12/90	85	1.8	1.5
		12/90-3/91	91	0.5	0.4
		4-6/91	48	0.9	0.8
		6-9/91	91	4.1	3.3
		9-11/91	62	1.3	1.1
		11/91-2/92	93	0.7	0.6
		2-5/92	83	0.5	0.4
		5-8/92	90	1.2	1.0
		8-11/92	99	1.0	0.8
			Station Mean	1.5	1.2
			Station Range	(0.5-4.1)	(0.4-3.3)
			Waterway Mean	1.7	2.6
			Waterway Range	(0.2-5.0)	(0.4-8.9)

Sedimentation Rate Calculations

- Mass Accumulation (g/cm2/yr)= [(P/A)/D] x Y
  - P= Amount of material collected (dry grams)
  - A= Collection area of sediment trap cylinders (cm2)
  - D= No. of days sediment trap was deployed
  - Y= No. of days in a year
- Accumulation Rate (cm/yr)= [Mass Accumulation (g/cm2/yr)/dry density (g/cm3)
  - Wet Density= Estimated from Puget Sound Density Model (Crecelius, 1989) using % solids data from in-situ bottom sediments.
  - Dry Density= [Wet Density x (Bottom Sediment % solids/100)]

Mass accumulation rates for Foss Waterway, on a dry weight basis, ranged from 0.2-5.0 g/cm^2/yr with a mean of 1.7±1.1 g/cm^2/yr. Based on averages, the highest mass accumulation rates in the waterway were measured at station TF-3 near the mouth of Wheeler-Osgood Waterway (mean= 2.0±1.1 g/cm^2/yr). In general, these data suggest that sedimentation in most of the waterway tends to be highest during the summer and early fall (June - September), and lowest during late winter and spring. This pattern suggests that seasonal variations in plankton populations may have a major influence on sedimentation rates in Foss Waterway. This finding is supported by the fact that, in general, TOC levels tended to peak between July and October. Other factors such as increases in vessel traffic during the summer which could resuspend bottom material, and runoff from the Puyallup River which typically peaks in June could also be contributing to this seasonal pattern. Predicted accumulation rates on the bottom ranged from 0.4-8.9 cm/yr with a mean of 2.6±2.0 cm/yr.

Bottom Sediments

The results of conventionals and metals analyses of bottom sediments collected from each of the sediment trap stations in December 1989 and January 1991 are shown in Table 9. TOC concentrations ranged from 1.4-8.9%. TOC tended to be highest at the head and decrease moving toward the mouth of the waterway. Grain size analysis indicated that most of the sediments collected from the upper half of the waterway consisted primarily of silt and clay size particles. Sediments at the mouth tended to have a higher percentage of sand size material.

Concentrations of "problem" metals in bottom sediments reported in mg/kg are summarized below;

Metal	Range	Mean	C.V.	N
• Cadmium	1.4-3.1	2.1	0.61	5
• Copper	89-250	160	0.37	5
• Mercury	0.09-0.92	0.63	0.52	5
• Nickel	34-86	50	0.41	5
• Lead	140-500	320	0.52	5
• Zinc	190-520	330	0.42	5

Table 9: Results of conventionals and metals analysis of bottom sediments from Thea Foss Waterway collected December 1989 and January 1991.

Location	Head near Twin 96" Drains			North of 15th Street Drain		Mouth of Wheeler-Osgood Waterway		Mouth near D-Street Tank Farms		
Station No.	TF-1			TF-2		TF-3		TF-4		
Sample No.	8113	8223/24*	8225	8114	8226	8115	8227	8116/17*	8118	8228
Collection Date	12/89	1/91	1/91(Rep)	12/89	1/91	12/89	1/91	12/89	12/89(Rep)	1/91
Total Solids (%)	36.8	40.4	40.6	47.5	43.5	38.4	42	49.0	75.1	72.6
Total Organic Carbon (%)	7.2	8.9	6.7	6.3	5.4	5.7	4.5	3.9	1.4	2.3
Grain Size (%)										
Gravel (>2mm)	0	0	1	6	0	0	0	0	5	5
Sand (2mm-62um)	25	30	43	53	13	10	22	28	86	79
Silt (62um-4um)	59	49	37	31	66	64	53	52	6	11
Clay (<4um)	16	22	19	10	21	26	25	20	3	5
Metals (mg/kg, dry)										
Cadmium	3.1	NA	NA	2.0	NA	3.6	NA	1.4	0.4	NA
Copper	170	NA	NA	140	NA	250	NA	140	89	NA
Mercury	0.71	NA	NA	0.84	NA	0.92	NA	0.58	0.09	NA
Nickel	86	NA	NA	44	NA	46	NA	42	34	NA
Lead	470	NA	NA	500	NA	300	NA	170	140	NA
Zinc	520	NA	NA	400	NA	360	NA	190	200	NA

*=Reported as mean of duplicates

NA=Not analyzed

For cadmium, nickel, and zinc the highest concentrations were measured at the head of the waterway. Copper and mercury were at a maximum near the mouth of Wheeler-Osgood Waterway. The lowest concentrations for all metals were present at the mouth of the waterway.

Results of semivolatiles analysis of bottom sediments collected in December 1989 are summarized in Table 10. Detected concentrations of "problem" organics reported in ug/kg were as follows:

Chemical	Range	Mean	C.V.	N
• LPAH	1800-12000	5200	0.81	5
• HPAH	9900-79000	31000	0.91	5
• Butyl benzyl phthalate	130-11000	3400	1.5	4
• Bis (2-ethyl hexyl) phthalate	2600-31000	15000	0.88	4

For the PAHs and closely related compounds concentrations were highest at the head of the waterway and decreased moving towards the mouth. Most of the phthalate esters were at a maximum near the 15th Street drain and at a minimum at the mouth of the waterway.

Tributyltin concentrations in bottom sediments, shown in Table 11, ranged from 10-410 ug/kg with a mean of 110 ug/kg. A similar pattern to TBT levels in SPM was observed for bottom sediments. The highest concentrations were present near the mouth of Wheeler-Osgood Waterway and the lowest typically occurred at the mouth of Foss Waterway. Tributyltin concentrations in Foss Waterway bottom sediments fall within the range of values (7-1900 ug/kg) reported for moorage areas inside several Puget Sound Marinas (Krone, *et al.*, 1989; Crecelius, *et al.*, 1989).

Selected metals and organics in Thea Foss Waterway surface sediments (top 2cm) collected in 1984, 1988, and 1989 are compared in Figures 4 and 5, respectively. In most instances copper and lead levels in 1984 are similar or lower to those measured in succeeding years. Exceptions were copper near Wheeler-Osgood Waterway, and lead near the 15th Street drain which were higher in later years. Mercury and zinc levels were higher in subsequent years at all locations tested except the mouth of the waterway. These data suggest that mercury and zinc levels in bottom sediments from the upper half of Foss Waterway are higher now than they have been historically.

For the organics, LPAH and HPAH levels in the present study were higher at the head of the waterway then those measured in 1984. Bis (2-ethyl hexyl) phthalate was also elevated at the head of the waterway and north of the 15th Street drain during the present study.

Table 10: Summary of semivolatile organics detected in bottom sediments from Thea Foss Waterway collected December 1989 (ug/kg,dry).

Location	Head near Twin 96" Drains	North of 15th Street Drain	Mouth of Wheeler-Osgood	Mouth near D-Street Tank Farms	
Station No.	TF-1	TF-2	TF-3	TF-4	
Sample No.	8113	8114	8115	8116/17*	8118
Depth @ MLLW (ft)	14	15	18	30	Rep
Acenaphthene	500	300 j	200 j	50 j	61 j
Acenaphthylene	310 j	190 j	280 j	150 j	190
Naphthalene	600	260 j	260 j	160 j	150 j
Fluorene	910	540	270 j	120 j	150 j
Anthracene	1900	1100	880	490	620
Phenanthrene	8000	4200	1400	800	1100
Sum LPAH	12000 j	6600 j	3300 j	1800 j	2300 j
Fluoranthene	19000	7400	3300	1800	1700
Benzo(a)anthracene	7200	2900	2000	880	970
Chrysene	8600	3600	2600	1100	1100
Pyrene	16000	6800	4500	2100	2300
Benzofluoranthenes	15000	5800	4600	2300	1600
Benzo(a)pyrene	5200	2600	2200	1100	900
Dibenzo(a,h)anthracene	1900	730	580	500	210
Indeno(1,2,3-cd)pyrene	3100	1800	980	780	500
Benzo(g,h,i)perylene	3300	1600	1200	980	630
Sum HPAH	79000	33000	22000	12000	9900
Total PAH	91000	40000 j	25000	14000 j	12000 j
2-methylnaphthalene	210	110 j	100 j	140 u	58 j
Carbazole	2200	1200	240 j	150 j	62 j
Dibenzofuran	300	230 j	120 j	80 j	34 j
Diethyl phthalate	160 u	260	120 j	140 u	74 u
Dimethyl phthalate	220 j	130 j	130 j	140 u	74 u
Butyl benzyl phthalate	2100	11000	340	130 j	74 u
Di-n-butyl phthalate	450	250000	150 u	140 u	74 u
Di-n-octyl phthalate	1800	540	150 u	140 u	74 u
Bis(2-ethylhexyl)phthalate	21000	31000	6100	2600	480 uj

*=Reported as mean of duplicates

u=Not detected at detection limit shown

j=Estimated concentration

=Problem chemical

Table 11: Results of butyltin analysis of bottom sediments from Thea Foss Waterway collected December 1989 and January 1991 (ug/kg, dry).

Location	Head near Twin 96" Drains			North of 15th Street Drain		Mouth of Wheeler-Osgood Waterway		Mouth near D-Street Tank Farms		
Station	TF-1			TF-2		TF-3		TF-4		
Sample No.	8113	8223/24*	8225	8114	8226	8115	8227	8116/17*	8118	8228
Collection Date	12/89	1/91	1/91(Rep)	12/89	1/91	12/89	1/91	12/89	12/89(Rep)	1/91
Monobutyltin	16 u	21	15	14 u	25	400	65	13 u	9.0 u	9.3
Dibutyltin	160	33	25	94	46	220	40	82	12	1.4 u
Tributyltin	160	65	59	110	90	410	110	120	15	10
Tetrabutyltin	19 u	5.9 j	5.5 u	17 u	5.3 u	20 u	5.4 u	16 u	11 u	3.5 u

*=Reported as mean of duplicates

u=Not detected at detection limit shown

j=Estimated concentration

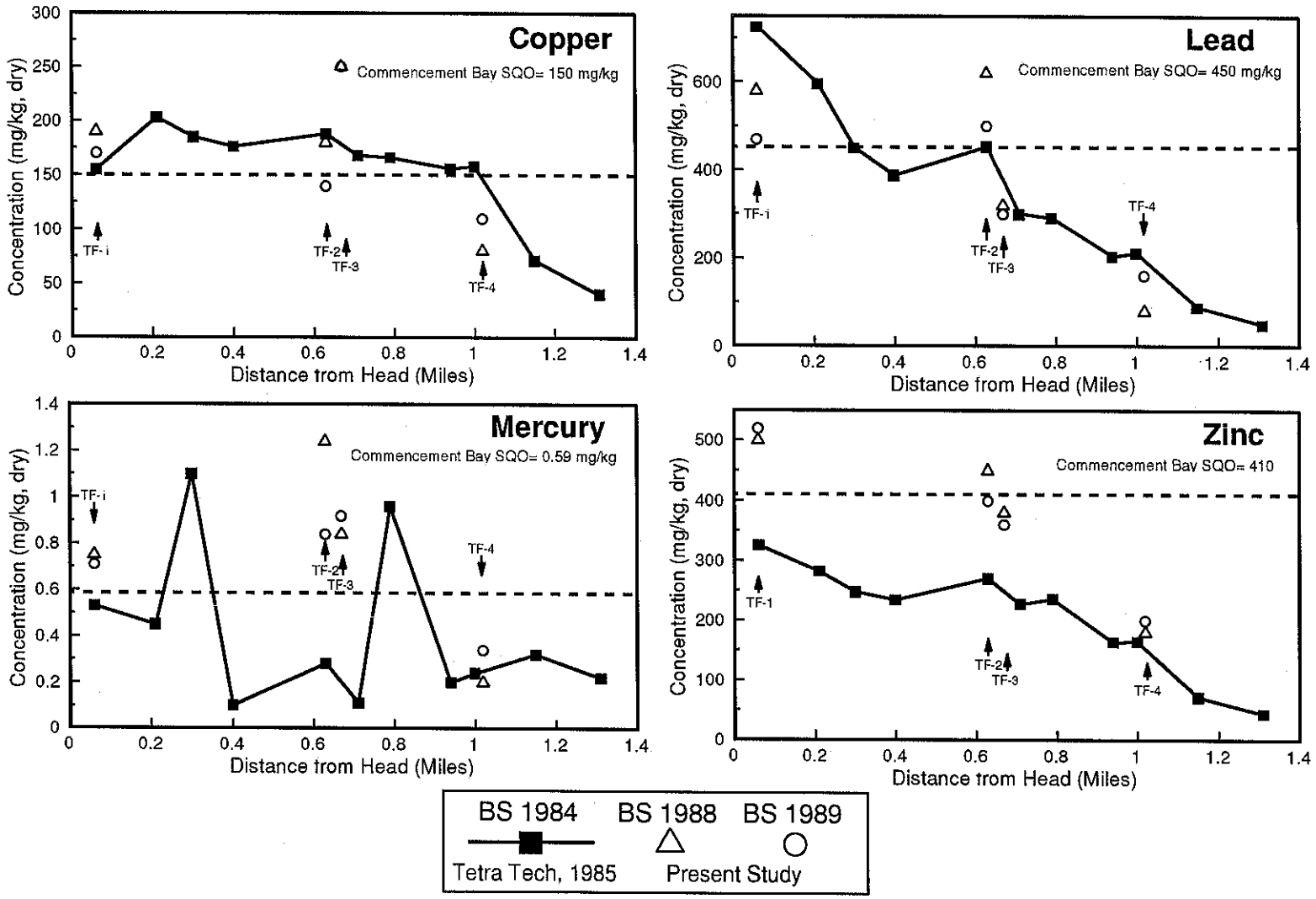

Figure 4: Comparison of copper, lead, mercury, and zinc concentrations in bottom sediments collected in 1984, 1988, and 1989 from Thea Foss Waterway.

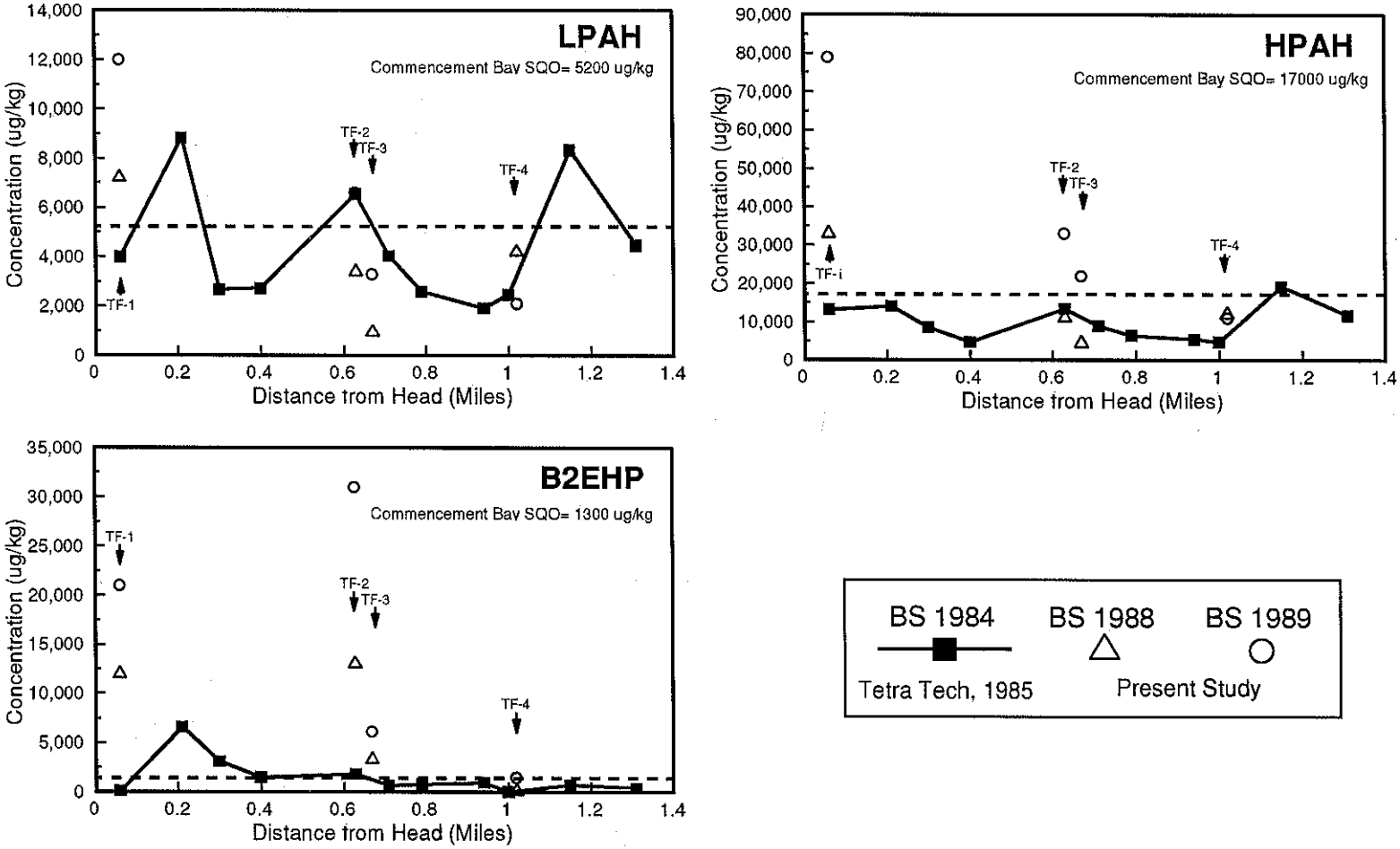

Figure 5: Comparison of LPAH, HPAH, and Bis (2-Ethyl Hexyl) Phthalate concentrations in bottom sediments collected in 1984, 1988, and 1989 from Thea Foss Waterway.

It should be noted that factors such as spatial and analytical variability between the CB/NT RI in 1984 and the present study may be contributing to the apparent trends in contaminant levels.

DISCUSSION

Contaminant Trends

Figure 6 compares concentrations of copper, lead, mercury, and zinc in SPM collected between 1988 and 1992 from Foss Waterway in an attempt to ascertain if source control efforts are succeeding in reducing inputs of these chemicals to the waterway. No significant changes in copper, lead, and zinc levels have occurred over the course of monitoring in the waterway. In contrast, mercury concentrations have steadily increased at the head and near the 15th Street drain between 1988 and 1992.

To better illustrate changes in mercury levels, Figure 7 presents a regression analysis of mercury concentrations versus time at three stations in Foss Waterway. Significant increases in mercury levels were noted at both the head ($r^2 = 0.53$, $P < 0.005$) and north of the 15th Street drain ($r^2 = 0.54$, $P < 0.02$) during the course of monitoring. Since monitoring began in 1988, mercury levels in SPM have almost doubled at these two stations. The lack of regression at the mouth of the waterway indicates that the trends for the other two stations is not an artifact of the laboratory analysis. As previously discussed in the quality assurance section, mercury results for the November 1991 - May 1992 collection period probably overestimate actual environmental levels by approximately 10%. With the affected mercury values reduced by 10% the regression analysis still indicates significant increases at both the head ($r^2 = 0.36$, $P < 0.05$) and north of the 15th street drain ($r^2 = 0.37$, $P < 0.05$).

Several storm drains in the upper half of Foss Waterway including the twin 96" drains and the 15th Street drain have been identified as sources of mercury (Smith, 1993). In addition, high concentrations of mercury (up to 120 mg/kg) have been detected in sludge samples from the inactive Surplus Steam Plant #1 (Tacoma-Pierce County Health Dept., 1988). This plant is located adjacent to the waterway on 0.29 acres between 11th and 15th Streets.

The apparent trends for mercury at the these two locations is disturbing since SPM concentrations have increased from levels below the Commencement Bay Sediment Quality Objective (SQO) when monitoring began to levels consistently above the SQO as of November 1992. A re-evaluation of potential sources of mercury at the head of the waterway and the area surrounding the 15th Street drain should be conducted.

Concentrations of LPAH, HPAH, and bis (2-ethyl hexyl) phthalate in SPM over the monitoring period are shown in Figure 8. In comparison to metals (c.v. = 0.056-0.24), organics concentrations tended to have a higher degree of temporal variability (c.v. = 0.47-1.4). The highest PAH concentrations were measured during January to June 1990. No clear trends in LPAH, HPAH, and bis (2-ethyl hexyl) phthalate levels were noted. However, differences in

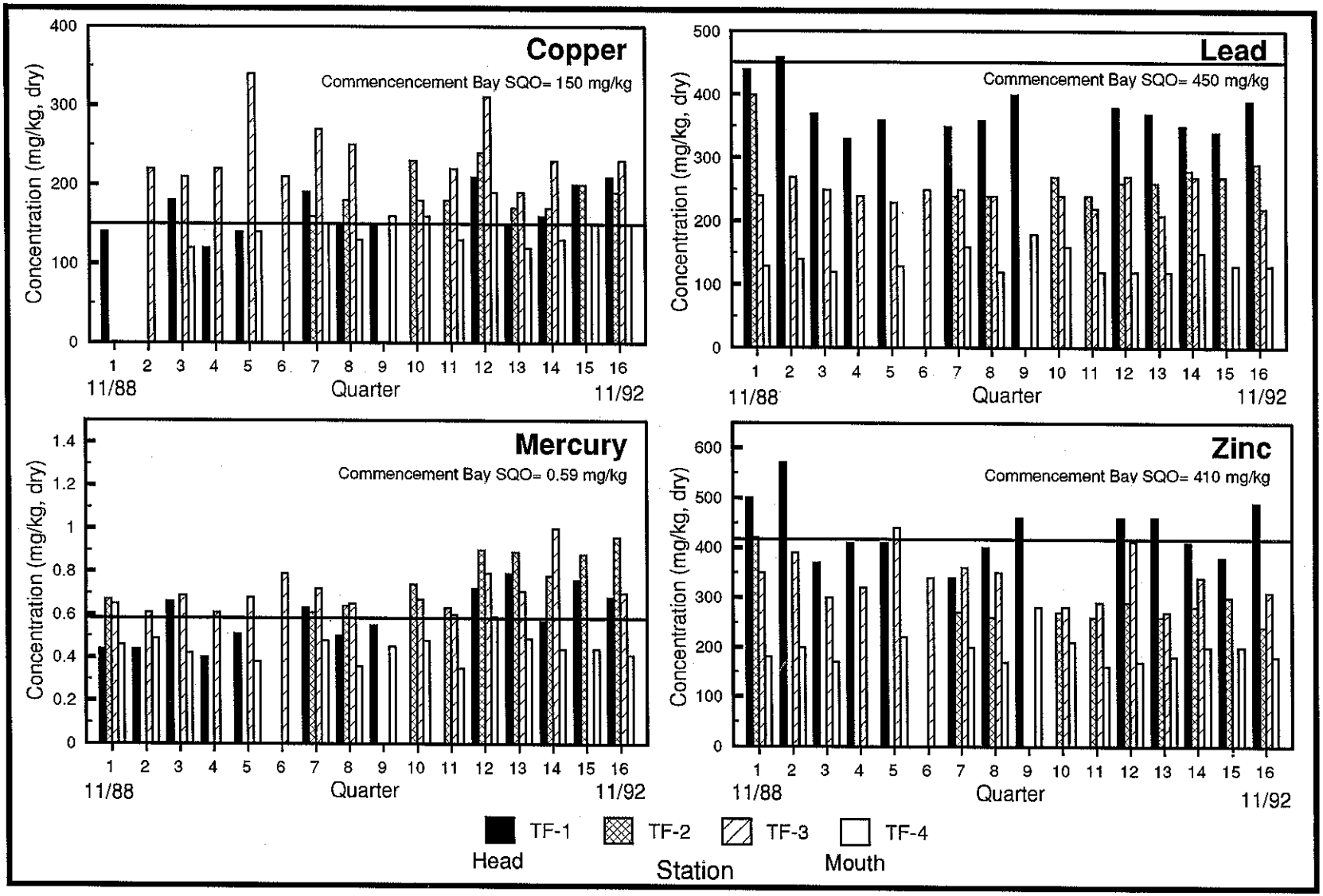

Figure 6: Concentrations of copper, lead, mercury, and zinc in settling particulate matter collected November 1988 to November 1992 from Thea Foss Waterway.

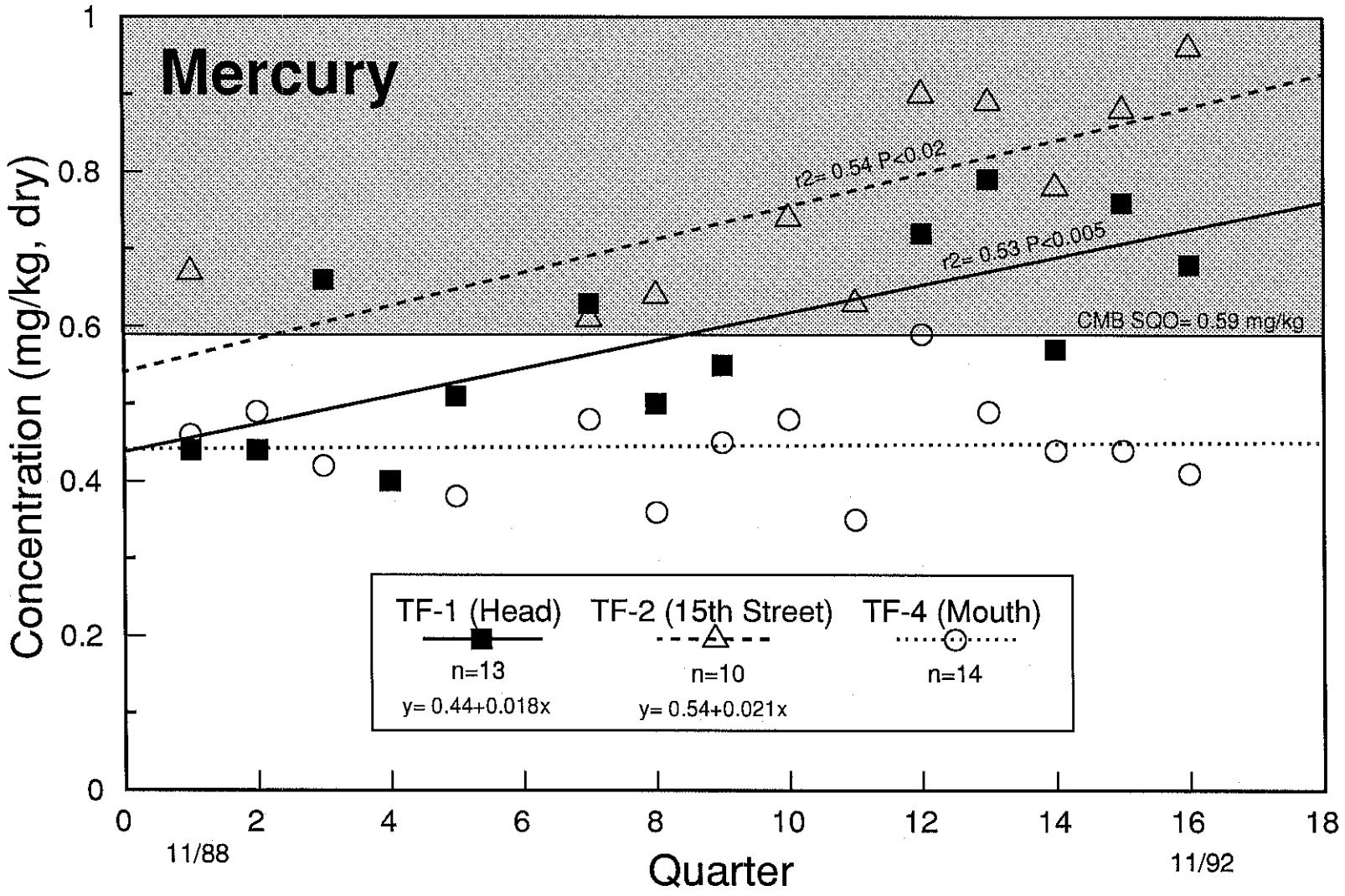

Figure 7: Trends in mercury levels associated with settling particulate matter at selected stations in Thea Foss Waterway, November 1988 to November 1992.

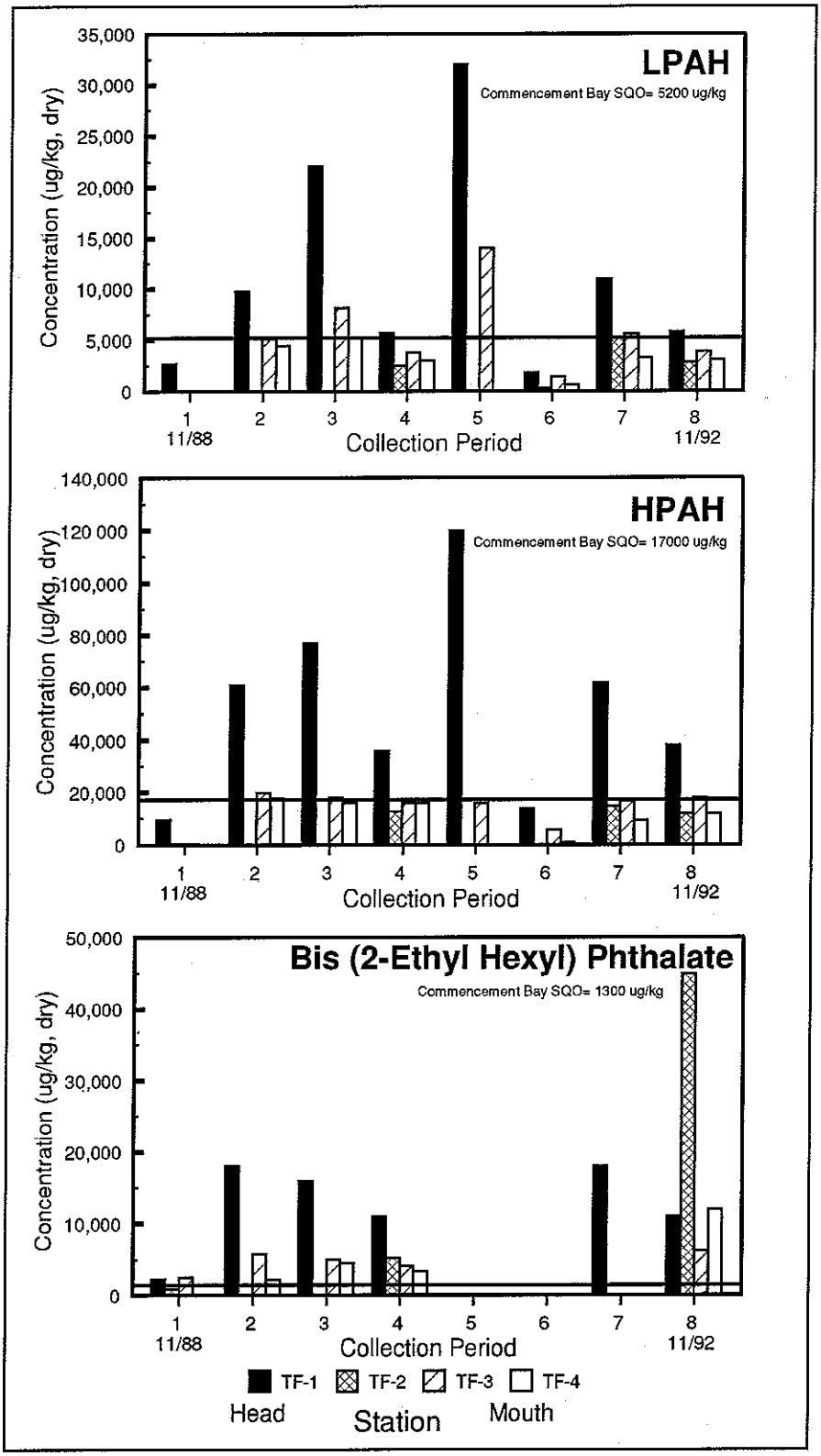

Figure 8: Concentrations of LPAH, HPAH and Bis (2-Ethyl Hexyl) Phthalate in settling particulate matter collected November, 1988 to November, 1992 from Thea Foss Waterway.

quantitation limits between monitoring periods hinder a detailed analysis of trends. It should be noted that as of April 1993 few source controls have actually been completed in Foss Waterway (Smith, 1993). Consequently, major reductions in contaminant levels entering the waterway would not be expected to be evident.

Comparison to Commencement Bay Sediment Quality Objectives

Of particular concern to source control efforts are chemicals which exceeded the SQOs (EPA, 1989a) in SPM. The SQOs are estimates of contaminant concentrations above which deleterious effects would always be observed in marine benthic communities. EPA, the lead agency for sediment remediation activities in the CB/NT is using the SQOs as cleanup objectives for contaminated sediments. Problem chemicals and selected non-priority chemical concentrations in SPM are compared to the SQOs in Appendix E- Tables E1 (metals) and E2 (organics).

Table 12 summarizes problem chemical concentrations in SPM, averaged between June 1989 and November 1992, which exceeded the SQO. Mean concentrations were selected for emphasis, to be more representative of average conditions in the waterway during the course of the study. In addition also shown in Table 12 is the percentage of samples exceeding the SQO for the chemicals listed.

A total of ten individual problem chemicals were measured above the SQOs in Foss Waterway SPM. The greatest number of exceedences (nine) were measured at the head of the waterway near the twin 96" drains. As would be expected the fewest number (three) were present at the mouth of the waterway. Copper and mercury were above the SQOs at three of the locations tested. Seven individual problem organics were above the SQOs in Foss Waterway. Bis (2-ethyl hexyl) phthalate exceeded the SQO throughout the waterway.

In addition to the problem chemicals, four non-priority chemicals (benzoic acid, diethyl phthalate, dimethyl phthalate, and di-n-butyl phthalate) were detected at levels above the SQOs listed in Appendix E- Table E2. Again the greatest number of exceedences were observed at the head of the waterway.

Tributyltin is the most toxic of the butyltins. While no SQO has been established for TBT, the Puget Sound Dredge Disposal Analysis (PSDDA) has adopted an Interim Screening Level (ISL) of 30 ug/kg (PSDDA, 1989). Sediments with TBT concentrations above the ISL are required to undergo biological toxicity testing. Average SPM concentrations of TBT (170-300 ug/kg) exceeded the PSDDA ISL at all stations.

Bottom sediments collected from each of the sediment trap stations are compared to the SQOs in Appendix E- Tables E3 (metals) and E4 (organics). "Problem" chemicals exceeding the SQOs in bottom sediments are summarized below;

Table 12: Summary of metals and organics concentrations averaged between June 1989 and November 1992 that exceeded the Commencement Bay Sediment Quality Objectives in Thea Foss Waterway settling particulate matter.

I. Problem Chemicals exceeding SQOs.

Station	Location	Chemical	Frequency of Exceedence (%)*
TF-1	Head near Twin 96" Drains	Copper	82
		Mercury	54
		Zinc	64
		LPAH	86
		HPAH	86
		Phenol	28
		4-Methylphenol	14
		Butyl benzyl phthalate	43
		Bis (2-ethyl hexyl) phthalate	71
TF-2	North of 15th Street Drain	Copper	100
		Mercury	100
		Phenol	20
		Bis (2-ethyl hexyl) phthalate	40
		Benzyl Alcohol	25
TF-3	Mouth of Wheeler-Osgood Waterway	Copper	100
		Mercury	100
		LPAH	57
		HPAH	57
		Phenol	14
		Bis (2-ethyl hexyl) phthalate	57
TF-4	Mouth near D-Street Tank Farms	4-Methylphenol	33
		Bis (2-ethyl hexyl) phthalate	67
		Benzyl Alcohol	17

II. Non-Priority chemicals exceeding SQOs.

Station	Location	Chemical	Frequency of Exceedence (%)*
TF-1	Head near Twin 96" Drains	Benzoic acid	86
		Diethyl phthalate	14
		Dimethyl phthalate	29
		Di-n-butyl phthalate	14
TF-2	North of 15th Street Drain	Benzoic acid	40
TF-3	Mouth of Wheeler-Osgood Waterway	Benzoic acid	71
TF-4	Mouth near D-Street Tank Farms	Benzoic acid	71

SQO=Commencement Bay Sediment Cleanup Objectives (EPA, 1989)

*=Number of samples exceeding SQO/total number of samples X 100

Location	Chemical
• TF-1 (Head)	Copper, mercury, lead, zinc, LPAH, HPAH, Butyl benzyl phthalate, and bis (2-ethyl hexyl) phthalate
• TF-2	Mercury, lead, LPAH, HPAH, butyl benzyl phthalate, and bis (2-ethyl hexyl) phthalate
• TF-3	Copper, mercury, HPAH, and bis (2-ethyl hexyl) phthalate
• TF-4 (Mouth)	Bis (2-ethyl hexyl) phthalate

underline= Also exceeded SQO in SPM

As was the case for SPM, the greatest number of individual exceedences (eight) were measured at the head of the waterway. Mercury was above the SQO at three of the four stations tested, while bis (2-ethyl hexyl) phthalate was at problem levels throughout the waterway. Concentrations of three additional non-priority chemicals (diethyl phthalate, dimethyl phthalate, and di-n-butyl phthalate) were also measured above the SQOs in bottom sediments. As was the case for SPM, average TBT concentrations (48-260 ug/kg) in bottom sediments exceeded the PSSDA ISL at all stations.

Problem Chemicals in Thea Foss SPM vs other Areas of Commencement Bay and Puget Sound

Shown in Table 13 is a comparison of problem chemicals in Foss SPM with contaminant levels in SPM from Hylebos and Sitcum Waterways. The SPM from Hylebos and Sitcum was also collected with the use of sediment traps and analyzed by identical methods. For perspective, also included are data on contaminant levels associated with muddy sediments from depositional areas in the central basin of Puget Sound (Tetra Tech, 1989, and PTI, 1991). Sediments from the central basin were included to reflect chemical concentrations associated with fine grained material not influenced by urban bays (*i.e.* reference areas).

TOC levels in Foss SPM were 2-3 times higher then those in Hylebos and Sitcum Waterways. Median concentrations of cadmium, and mercury in Foss Waterway were also 2-3 times higher then those in Hylebos Waterway. Similar concentrations of copper, nickel, and zinc were present in all three waterways. LPAH and HPAH levels in Foss Waterway were higher by a factor of 2-3 compared to the other waterways tested.

Compared to muddy sediments from the central basin, all metals except nickel were elevated by a factor of 2-10. Nickel concentrations were similar in both areas. The LPAH and HPAH levels were elevated by at least an order of magnitude in Foss SPM compared to the central basin sediments.

Table 13: Comparison of selected problem chemicals detected in settling particulate matter (SPM) from Thea Foss waterway during the present study with other available data on contaminant levels associated with SPM from Hylebos and Sitcum Waterways and bottom sediments (BS) from the Central Puget Sound Basin.

Location	Thea Foss	Hylebos	Sitcum	Central Basin*
Sample Type	SPM	SPM	SPM	BS
Collection Period	11/88-11/92	7/90-11/91	7/90-6/91	3/89-3/90
Number of Samples	23-51	16-27	10-17	11
Total Organic Carbon (%)	5.4 (1.9-11)	3.2 (1.7-7.3)	1.8 (1.4-3.7)	1.8 (1.6-2.5)
Metals (mg/kg, dry)				
Cadmium	2.3 (0.8-3.7j)	0.7 (0.4-1.5)	-	0.3 (0.2j-0.3j)
Copper	180 (120-340)	150 (110-410)	130 (66-190)	38 (34-53)
Mercury	0.63 (0.35-1.0j)	0.29 (0.16-0.53)	-	0.13 (0.11u-0.21)
Lead	250 (120-460)	98 (48-240)	270 (52-370)	22j (18j-40)
Nickel	39 (28-81)	41 (30-53)	-	40 (36-43)
Zinc	300 (160-570)	200 (120-370)	510 (100-580)	99 (89-110j)
Organics (ug/kg, dry)				
LPAH	4500j (250j-32000J)	1900j (190j-15000j)	2200j (320-8600j)	130j (110j-180j)
HPAH	16000 (120-120000j)	7800j (4400j-49000j)	6900j (880-21000j)	380j (240j-850j)

median (range)
*=Central basin muddy sediments (>67% fines) from deep areas (>150m), includes stations 24, 29, and 38.
-=No data
u=Not detected at detection limit shown
j=Estimated concentration
nd=Not detected
Data Sources
Thea Foss- Present Study; Norton, 1990.
Hylebos- Norton and Barnard, 1992b
Sitcum- Norton and Barnard, 1992b.
Central Basin- PSAMP (Puget Sound Ambient Monitoring Program) Tetra Tech, 1989 and PTI, 1991.

Sedimentation Rates in Thea Foss Waterway vs other Areas of Commencement Bay and Puget Sound

To place sedimentation rates for Foss Waterway into perspective, Table 14 summarizes rates reported for other parts of Commencement Bay and Puget Sound. Mean sedimentation rates for Foss, Hylebos, and Sitcum Waterways determined from sediment trap data (gross sedimentation) agreed within a factor of 2. The highest average rates were measured in Sitcum Waterway (3.5±1.2 g/cm^2/yr), followed by Hylebos (2.1±0.8 g/cm^2/yr), and then Thea Foss Waterway (1.7±1.1 g/cm^2/yr).

Based on a re-evaluation of two Pb-210 dated cores collected during the CB/NT RI, net sedimentation in Foss Waterway was estimated to be 0.3 g/cm^2/yr at the head and 0.45 g/cm^2/yr at the mouth (EPA, 1992). The uncertainty associated with these measurements was not reported. Net sedimentation rates generally agree within a factor of 3 at the head and 2 at the mouth of Foss Waterway compared to net sedimentation rates (0.94±0.5 g/cm^2/yr) reported for other Commencement Bay Waterways. In addition, net sedimentation rates in Foss are generally within a factor of 2 compared to mean rates reported for various parts of Puget Sound.

Comparison of sedimentation rates from sediment traps (gross sedimentation) and rates from Pb-210 dated cores (net sedimentation) have been used in other investigations to estimate bottom sediment resuspension rates (Baker, *et al.*, 1991). Comparing net sedimentation rates at the head (0.3 g/cm^2/yr) and the mouth (0.45 g/cm^2/yr) to gross sedimentation at the nearest sediment trap locations (TF-1= 1.6±0.9 g/cm^2/yr and TF-4=1.5±1.2 g/cm^2/yr), indicates that resuspension is approximately 1.3 g/cm^2/yr and 1.1 g/cm^2/yr at the head and mouth, respectively. These rates are similar to those measured in Hylebos Waterway (1.0-1.1 g/cm^2/yr), and approximately one-half of the resuspension rates reported for Sitcum Waterway (2.2 to 2.9 g/cm^2/yr), (Norton and Barnard, 1992a,b). In addition, they fall within the range of values (0.4-3.6 g/cm^2/yr) reported by Patmont and Crecelius (1991) for other urban embayments in Puget Sound.

Resuspension estimates for Foss Waterway suggest that 70-80 percent of the material collected by the sediment traps could be recent bottom sediments which have been resuspended. Sillcox (*et al.*, 1981) in a study of physical transport processes in Elliot Bay reports that unconsolidated course silt can be resuspended when water speeds are about 23.5 cm/sec at 2 m above the bottom. During deployment of the current meters in Foss Waterway (1m above the bottom), velocities in excess of 22 cm/sec occurred <0.2% of the time. These data suggest that other factors such as vessel activities may play an important role in resuspending sediments in Foss Waterway. Given the low current velocities measured in the waterway the material being resuspended is most likely recent fine particulates which have not yet been consolidated on the bottom. While the exact proportion of "new" vs. "old" material being collected by the traps cannot be reliably determined with the available data, it is fair to assume that the trapped material is representative of sediments which are mobile in the waterway.

Table 14: Comparison of sediment accumulation rates for Thea Foss Waterway obtained from sediment traps with values reported for other parts of Commencement Bay and Puget Sound.

Source	Location	Method	Sedimentation Rate(1) (g/cm2/yr)	(cm/yr)
		GROSS SEDIMENTATION		
Present Study	Thea Foss	Sediment Trap	1.7 (0.2-5.0)	2.6 (0.4-8.9)
Norton and Barnard, 1992a,b	Hylebos WW	Sediment Trap	2.1 (0.7-3.8)	3.1 (0.9-7.2)
	Sitcum WW	" "	3.5 (2.1-5.7)	3.7 (2.3-5.7)
		NET SEDIMENTATION		
Tetra Tech and PTI, 1987 (3)	Head of Thea Foss WW	Pb-210 cores (4)	0.30	0.45
	Mouth of Thea Foss WW	Pb-210 cores (4)	0.45	0.67
	CMB Waterways(2)	Pb-210 cores (4)	0.94 (0.22-1.4)	1.3 (0.27-1.8)
Carpenter et al., 1985	Near Browns Pt.	Pb-210 cores	0.24 (0.2-0.28)	0.42 (0.25-0.58)
	Puget Sound	" "	0.43 (0.046-1.2)	0.68 (0.04-2.4)
Lavelle et al., 1986	Puget Sound	Pb-210 cores	0.72 (0.26-1.2)	1.4 (0.53-2.48)
Bloom and Crecelius, 1987	Puget Sound	Pb-210 cores	0.64 (0.27-1.4)	-

(1)=Mean(range)

(2)=Includes- Hylebos, Middle, St. Paul, Milwaukee, and Sitcum Waterways

(3)= Original Report- Re-calculated and reported in (EPA, 1992).

(4)=Estimated values

-=No data

CONCLUSIONS

Although the spatial distribution of problem chemicals measured in both SPM and bottom sediments in Thea Foss Waterway is generally consistent with historical information on sediment contamination, several results deserve special attention. Mean concentrations of ten individual problem chemicals exceeded the Commencement Bay Sediment Quality Objectives (SQOs) in SPM. Mercury data for SPM indicates that concentrations at the head of the waterway and near the 15th Street drain have increased almost two-fold since sediment trap monitoring began in late 1988. The apparent trend for mercury is disturbing since concentrations in SPM were typically below the SQO when monitoring began to levels consistently above the SQO as of November 1992. This finding is supported by the fact that, on average, bottom sediments collected in 1988 and 1989 at these two locations also have higher mercury concentrations compared to samples taken in 1984.

Overall, the data collected suggest that concentrations of most problem chemicals in Thea Foss Waterway sediments have not decreased since the CB/NT RI was conducted in 1984. An exception is lead at the head of the waterway which appears to be lower. These results are not unexpected since few source controls have actually been implemented in the waterway as of April 1993.

The major findings of sediment monitoring conducted between June 1989 and November 1992 in Thea Foss Waterway are summarized below;

- Mean concentrations of ten individual problem chemical in SPM were high enough to adversely affect marine benthic communities, based on comparisons with the Commencement Bay Sediment Quality Objectives (SQOs). The greatest number of exceedences (9) were measured at the head of the waterway near the twin 96" drains. Problem chemicals with average concentrations exceeding the SQOs in SPM are listed below;

Location	Chemical
• TF-1 (Head)	Copper, mercury, zinc, LPAH, HPAH, phenol, 4-methyl phenol, butyl benzyl phthalate, and bis (2-ethyl hexyl) phthalate
• TF-2	Copper, mercury, phenol, bis (2-ethyl hexyl) phthalate, and benzyl alcohol
• TF-3	Copper, mercury, LPAH, HPAH, phenol, bis (2-ethyl hexyl) phthalate
• TF-4 (Mouth)	4-methyl phenol, bis (2-ethyl hexyl) phthalate, and benzyl alcohol

In addition, average concentrations of four non-priority (benzoic acid, diethyl phthalate, dimethyl phthalate, and di-n-butyl phthalate) chemicals were also measured above the SQOs. Tributyltin concentrations exceeded the Puget Sound Dredge Disposal Analysis Interim Screening Level of 30 ug/kg at all stations.

- Relatively high concentrations of Total Organic Carbon (TOC) were present in Foss Waterway, especially at the head. The mean concentration at the head (8.1%) was elevated by almost two times the mean concentration at the mouth (4.5%) at the waterway. TOC was identified as a problem chemical at the head of the waterway during the Commencement Bay Nearshore/Tideflats Remedial Investigation.

- The highest concentrations of cadmium, nickel, lead, and zinc were measured at the head of the waterway. The highest copper concentrations were typically measured near the mouth of Wheeler-Osgood Waterway. On average, mercury levels were at a maximum near the 15th Street drain. The lowest metals concentrations were consistently present at the mouth of the waterway.

- Mercury concentrations in Foss Waterway SPM have increased almost two-fold at the head and near the 15th Street drain since sediment monitoring began in 1988. At a minimum, increasing trends for mercury are statistically significant at the 95% confidence level.

- Thirty-one semivolatile organics were quantified in SPM, six of which are identified as problem chemicals. As was the case for metals the highest concentrations of most problem organics typically occurred at the head of the waterway and the lowest levels were measured at the mouth. In particular high concentrations of PAHs were present at the head. In contrast, bis (2-ethyl hexyl) phthalate peaked near the 15th street drain and 4-methyl phenol was at a maximum at the mouth of the waterway. Tributyltin which is still used as an active ingredient in antifouling paints for some applications was detected throughout the waterway at concentrations ranging from 11-560 ug/kg.

- Median TOC, LPAH, and HPAH concentrations were 2-3 times higher in Foss SPM compared to SPM from Hylebos and Sitcum Waterways. Mercury was also elevated by a factor of 2 compared to SPM from Hylebos Waterway.

- Sedimentation rates for Foss Waterway calculated from sediment trap data ranged from 0.2-5.0 g/cm^2/yr with a mean of 1.7$\pm$1.1 g/cm^2/yr. Based on a comparison of gross (sediment traps) and net (Pb-210 cores) sedimentation rates, estimated bottom sediment resuspension rates are 1.3 and 1.1 g/cm^2/yr at the head and mouth, respectively. These data suggest that somewhere in the range of 70-80 percent of the material collected by the traps is probably recently deposited particulates which have not been consolidated on the bottom. While the exact proportion of "new" vs. "old" material being collected by the traps cannot be reliably determined with the available data, it is fair to assume that the material collected is representative of sediments which are mobile in the waterway.

- Current velocities were generally slow in the waterway during deployment of the current meters (spring tidal series), ranging from 2-28 cm/sec with a geometric mean of 2.3 cm/sec. The lowest velocities were measured at the head, where currents are $\leq$4 cm/sec 90% of the time. This result suggest that poor flushing characteristics are present in this area of the waterway. For comparison, velocities measured in other Commencement Bay waterways between December 27, 1990, and February 5, 1991, were as follows: Hylebos 2-85 cm/sec, Geo. mean= 5.5 cm/sec; Sitcum 2-150 cm/sec, Geo. mean= 3.4 cm/sec.

REFERENCES CITED

APHA-AWWA-WPCF, 1985. Standard Methods for the Examination of Water and Wastewater. 16th ed.

Baker, E.T., H.B. Milburn and D.A. Tennant, 1988. Field Assessment of Sediment Trap Efficiency under Varying Flow Conditions. J. Mar. Res., 46:573-592.

Baker, J.E., S.J. Eisenreich, and B.J. Eadia, 1991. Sediment Trap Fluxes and Benthic Recycling of Organic Carbon, Polycyclic Aromatic Hydrocarbons, and Polychlorobiphenyl Congeners in Lake Superior. Environmental Science and Technology, Vol. 25: 500-509.

Bloom, N. and E.A. Crecelius, 1987. Distribution of Silver, Mercury, Lead, Copper and Cadmium in Central Puget Sound Sediments. Mar. Chem., 21:377-390.

Buesseler, K.O., 1991. "Do Upper Ocean Sediment Traps Provide an Accurate Record of Particle Flux." Nature Vol 353, No. 3, October 1991.

Butman, C.A., 1986. Sediment Trap Biases in Turbulent Flows; Results from a Laboratory Flume Study. J. Mar. Res., 44:645-693.

Butman, C.A., W.D. Grant and K.D. Stolzenbach, 1986. Predications of Sediment Trap Biases in Turbulent Flows: A Theoretical Analysis Based on Observations from the Literature. J. Mar. Res., 44:601-644.

Carpenter, R., M.L. Peterson and J.T. Bennett, 1985. PB-210 Derived Sediment Accumulation and Mixing Rates for the Greater Puget Sound Region. Mar. Geo. 64:291-312.

Crecelius, E.A, T.J. Fortman, S.L. Kiesser, C.W. Apts, and O.A. Cotter, 1989. Survey of Contaminants in Two Puget Sound Marinas. Prepared for the Puget Sound Estuary Program. EPA Region X, Seattle, WA. EPA 910/9-89-014.

EPA, 1986. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods. 3rd ed. Office of Solid Waste and Emergency Response, Washington, DC.

EPA, 1989a. Commencement Bay Nearshore/Tideflats: Record of Decision. U.S. Environmental Protection Agency Region 10, Seattle, WA.

EPA, 1989b. Semivolatile Organic Compounds by Isotope Dilution GC/MS-Revision C. EPA Office of Water Regulations and Standards, Industrial Technology Division. Office of Water, Wash., D.C.

EPA, 1992. Source Control Strategy. Commencement Bay Nearshore/Tideflats Superfund Site. U.S. Environmental Protection Agency Region 10, Seattle, WA.

Holme, N.A. and A.D. McIntyre, 1971. Methods for Study of the Marine Benthos. Internat. Biol. Prog. Handbook No. 16.

Krone, C.A., D.W. Brown, D.G. Burrows, S.L. Chan, and U. Varanasi, 1989. Butyltins in Sediment from Marinas and Waterways in Puget Sound, Washington State, U.S.A. Marine Pollution Bulletin, Vol. 20, No. 10. pp 528-531.

Larsson, U., S. Blomquist, and B.A. Abrahamsson, 1986. A New Sediment Trap System. Mar. Ecol. Prog. Ser., 31:205-207.

Lavelle, J.W., G.J. Massoth and E.A. Crecelius, 1986. Accumulation Rates of Recent Sediments in Puget Sound, Washington. Mar. Geo., 72:59-70.

Nielson, K.K., and R.W. Sanders, 1983. Multi-element Analysis of Unweighed Biological and Geological Samples using Backscatter and Fundamental Parameters. Adv. X-Ray Anal., 26:385-390.

Norton, D., and A. Johnson, 1984. Metals in City Waterway Sediment off American Plating Co., Inc., J.M. Martinac Shipbuilding Corp., and Fick Foundry Co., April 1984. Completion Report on WQIS Project No. 5 (Part 2) for the Commencement Bay Nearshore/Tideflats Remedial Investigation. Memorandum to Jim Krull. Washington St. Dept. of Ecology, Olympia, WA.

Norton, D, 1990. Use of Sediment Traps to Monitor Contaminant Flux to City Waterway Sediments: Interim Report. Washington State Department of Ecology, Olympia, WA.

Norton, D., and B. Barnard, 1992a. Spatial and Temporal Trends in Contaminant Levels Associated with Settling Particulate Matter in Sitcum Waterway (Commencement Bay) July 1990 to June 1991. Washington State Department of Ecology, Olympia, WA.

Norton, D., and B. Barnard, 1992b. Spatial and Temporal Trends in Contaminant Levels Associated with Settling Particulate Matter in Hylebos Waterway (Commencement Bay) July 1990 to November 1991. Washington State Department of Ecology, Olympia, WA.

Patmont, C.R., and E.A. Crecelius, 1991. Natural Sediment Recovery in Contaminated Embayments of Puget Sound. Vol 1. Puget Sound Research Proceedings. Puget Sound Water Quality Authority. Seattle, WA.

PSEP, 1988. Everett Harbor Action Program: Analysis of Toxic Problem Areas. Puget Sound Estuary Program. Prepared for EPA Region 10, Office of Puget Sound by PTI and Tetra Tech, Inc. Final Report TC-3338-26.

PSDDA, 1989. PSDDA Management Plan Report: Unconfined Open Water Disposal of Dredged Material, Phase II. Joint Report by the ACOE, EPA, Wash. St. Dept. of Natural Resources, and Wash. St. Dept. of Ecology.

PTI, 1991. Marine Sediment Monitoring Data Validation Reports. Puget Sound Ambient Monitoring Program, 1990. Prepared for the Washington State Department of Ecology.

Sillcox, R.L., W.R. Geyer, and G.A. Cannon, 1981. Physical Transport Processes and Circulation in Elliot Bay. NOAA Technical Memorandum OMPA-8.

Smith, D., 1993. Personal Communication. Project Manager for the Commencement Bay Urban Bay Action Team, Washington State Department of Ecology, Olympia, WA.

Tacoma-Pierce County Health Dept., 1988. Preliminary Environmental Assessment of the Surplus Steam Plant No. 1 Site. Prepared for the Tacoma Light Division.

Tetra Tech, 1985. Commencement Bay Nearshore/Tideflats Remedial Investigation. Vols. 1-2, Final Report. Prepared for the Washington State Department of Ecology and U.S. Environmental Protection Agency, EPA-910/9-85-134b.

Tetra Tech, 1986. Recommended Protocols for Measuring Selected Environmental Variables in Puget Sound. Prepared for the Puget Sound Estuary Program. Final Report No. TC-3991-04.

Tetra Tech and PTI, 1987. Commencement Bay Nearshore/Tideflats Feasibility Study: Assessment of the Potential Success of Source Control. Final Report. Prepared for the Washington State Department of Ecology and U.S. Environmental Protection Agency. Report No. TC-3218-05.

Tetra Tech, 1989. Marine Sediment Monitoring: Puget Sound Ambient Monitoring Program. Prepared for Washington State Department of Ecology.

USGOFS, 1989. Sediment Trap Technology and Sampling, Report of the United States Global Ocean Flux Study Working Group on Sediment Traps Technology and Sampling. Univ. of Southern Mississippi, Center for Marine Science.

Verschueren, K. 1983. Handbook of Environmental Data on Organic Chemicals. 2nd ed. Van Nostrand Reinhold Co., Inc. N.Y.

APPENDICES

Appendix A: Sediment Trap Design

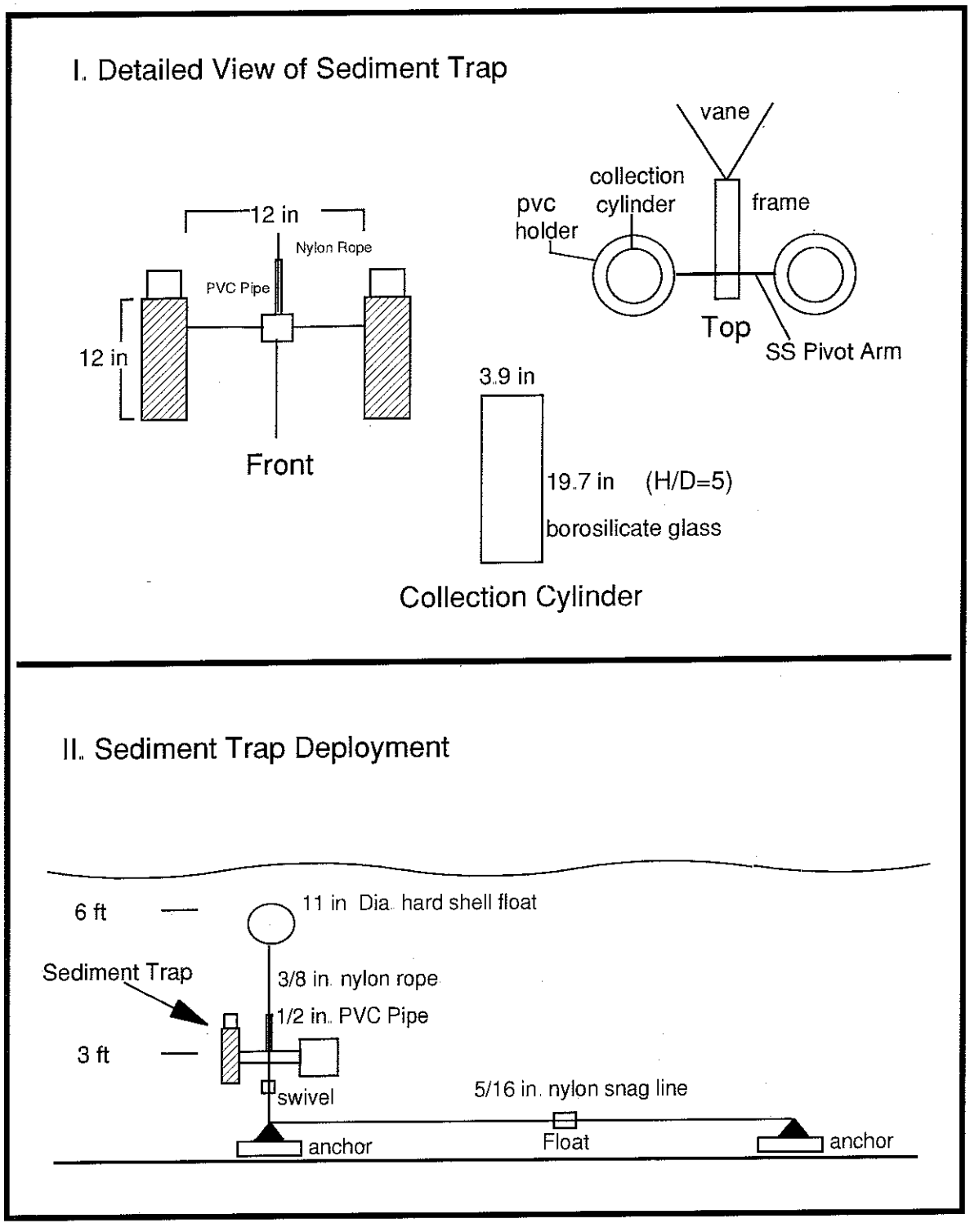

Figure A1: Schematic of Thea Foss Waterway sediment traps.

Appendix B: Quality Assurance Data

Table B1: Summary of blind field duplicate results(1) for metals in settling particulate matter (SPM) and bottom sediments (BS) from Thea Foss Waterway collected June 1989 to November 1992 (mg/kg, dry).

Sample No.	498093	498128		358108	358106		408112	408123		528288	528311		268319	268326		518508	518509	
Collection Date	5-8/89	-		1-7/90	-		7-10/90	-		10-12/90	-		1-6/91	-		6-9/91	-	
Sample Type	SPM	SPM	RPD	SPM	SPM	RPD	SPM	SPM	RPD	SPM	SPM	RPD	SPM	SPM	RPD	SPM	SPM	RPD
Cadmium	2.85	3	-5.1	2.07	1.92	7.5	3.26	2.91	11.3	2.02	2.44	-18.8	1.3	1.5	-14.3	1.9	1.8	5.4
Copper	182	179	1.7	355	326	8.5	186	185	0.5	142	148	-4.1	166	162	2.4	128	134	-4.6
Mercury	0.66	0.68	-3.0	0.71	0.66	7.3	0.65	0.59	9.7	0.48	0.54	-11.8	0.47	0.49	-4.2	0.36	0.34	5.7
Lead	369	375	-1.6	233	225	3.5	358	343	4.3	365	359	1.7	159	160	-0.6	115	115	0.0
Nickle	67	58	14.4	44.8	41.5	7.6	60.1	64.1	-6.4	71.1	74.6	-4.8	34	32	6.1	29	27	7.1
Zinc	372	377	-1.3	450	436	3.2	332	345	-3.8	407	389	4.5	214	214	0.0	157	156	0.6

Sample No.	518519	518516		268419	268420		498313	498314		498329	498330		498116	498117	
Collection Date	9-11/91	-		11/91-5/92	-		5-8/92	-		8-11/92	-		12/89	-	
Sample Type	SPM	SPM	RPD	SPM	SPM	RPD	SPM	SPM	RPD	SPM	SPM	RPD	BS	BS	RPD
Cadmium	3.1	3	3.3	2.65	2.56	3.5	3.1 j	3.1 j	0.0	1.5 j	1.53 j	-2.0	1.42	1.47	-3.5
Copper	309	312	-1.0	170	167	1.8	196	197	-0.5	148	148	0.0	134	146	-8.6
Mercury	0.79	0.8	-1.3	0.79 j	0.77 j	2.6	0.91 j	0.86 j	5.6	0.41 j	0.41 j	0.0	0.62	0.54	13.8
Lead	271	271	0.0	283	278	1.8	271	268	1.1	128	127	0.8	157	175	-10.8
Nickle	36	42	-15.4	41.8	40.3	3.7	37	35.1	5.3	30	31.7	-5.5	41	43	-4.8
Zinc	422	402	4.9	286	279	2.5	299	294	1.7	187	177	5.5	191	192	-0.5

RPD=Relative Percent Difference=[(x-y)/((x+y)/2)*100]

(1)=All samples analyzed by Battelle Northwest- Sequim, Wa.

j=Estimated concentration

Table B2: Summary of blind field duplicate results for selected semivolatile organics and butyltins detected in settling particulate matter (SPM) and bottom sediments (BS) from Thea Foss Waterway June 1989 to November 1992 (ug/kg, dry).

Sample No.	498096	498097		358117	358111		528303	528313		268322	268327		518525	518526	
Collection Date	5-12/89	-	RPD	i-6/90	-	RPD	7-12/90	-	RPD	i-6/91	-	RPD	6-11/91	-	RPD
Sample Type	SPM	SPM	(%)	SPM	SPM	(%)	SPM	SPM	(%)	SPM	SPM	(%)	SPM	SPM	(%)
Semivolatiles															
Laboratory		ARI			ARI			ARI			Manchester			Manchester	
Sum LPAH	9800 j	9100 j	7.4	5400 j	4300 j	23	4200 j	3900 j	7.4	5400 j	4300 j	23	1100 j	1700 j	-43
Sum HPAH	63000 j	58000	8.3	17000	15000 j	13	16000 j	15000 j	6.5	4800 j	3700 j	26	4000	7200 j	-57
Sum Phenols	3700	2800 j	28	-	-	-	690	410	51	1100 j	2000 j	-58	290	400 j	-32
Sum Phthalates	24000 j	20000 j	18	5800 j	4800	19	5000 j	4100 j	20	-	-	-	-	-	-
Butyltins															
Laboratory		Manchester			Manchester			Manchester			Manchester			Manchester	
Tributyltin	360	530	-38	-	-	-	-	-	-	-	-	-	71	74	-4.1

RPD=Relative Percent Difference=[(x-y)/((x+y)/2)*100]

-=No data

j=Estimated concentration

Manchester-Ecology/EPA Manchester Laboratory Manchester, Wa.

ARI-Analytical Resources Inc. Seattle, Wa.

Table B2 (continued): Summary of blind field duplicate results for selected semivolatile organics and butyltins detected in settling particulate matter (SPM) and bottom sediments (BS) from Thea Foss Waterway collected June 1989 to November 1992 (ug/kg, dry).

Sample No.	268426	268427		498331	498332		498116	498117		48223	48224	
Collection Date	12/91-5/92	-	RPD	5-11/92	-	RPD	12/89	-	RPD	1/91	-	RPD
Sample Type	SPM	SPM	(%)	SPM	SPM	(%)	BS	BS	(%)	BS	BS	(%)
Semivolatiles												
Laboratory		Manchester			Manchester			ARI			Manchester	
Sum LPAH	12000 J	8900 J	30	4900 J	6600	-30	1500 J	1700 J	-13	-	-	-
Sum HPAH	53000	69000 J	-26	32000	44000	-32	12000 J	11000 J	9	-	-	-
Sum Phenols	1800	700	88	140 J	99 J	34	-	-	-	-	-	-
Sum Phthalates	30000 J	21000 J	35	15000	7800	63	2800 J	2500 J	11	-	-	-
Butyltins												
Laboratory		Manchester			Manchester			Manchester			Manchester	
Tributyltin	590 J	370 J	46				130	98	28	74	56	28

RPD=Relative Percent Difference=[(x-y)/((x+y)/2)*100]

-=No data

J=Estimated concentration

Manchester-Ecology/EPA Manchester Laboratory Manchester, Wa.

ARI-Analytical Resources Inc. Seattle, Wa.

Case Narratives for Semivolatile Organics Analysis

Particulates and bottom sediment- 5-12/89

STATE OF WASHINGTON DEPARTMENT OF ECOLOGY
MANCHESTER ENVIRONMENTAL LABORATORY
7411 Beach Drive E., Port Orchard, WA 98366

DATA REVIEW
June 25, 1991

Project: City Waterway - Tacoma

Samples: 89 - 498096, 498097, 498101, 498105, 498113, 498114, 498115, 498116, 498117, and 498118,

Laboratory: Analytical Resources Incorporated 4193 - WDOE

By: Dickey D. Huntamer

Through: Stuart Magoon

CASE SUMMARY

These analyses were reviewed for qualitative and quantitative accuracy, validity and usefulness. Sample analysis used EPA Method 1625 procedures. Extraction and cleanup methods were consistent with SW 846 Methods for soil samples. Specific methods used and problems incurred during the analysis of these samples are detailed in the case narrative and will not be addressed here. Analytical problems associated with QA/QC will be noted and referenced to the case narrative where appropriate.

There is no need to assimilate the "dilution factor" or "sample wt/vol" into the final values reported; these calculations have already been figured into the reported values. The soil results are calculated on a dry weight basis.

SEMIVOLATILE FRACTION

Method: EPA Method 1625

Matrix: Soil

Holding times:

All of the samples were analyzed within the recommended 14 day holding time.

Blank:

Three target compounds, pyrene, fluoranthene and bis-(2-ethylhexyl) phthalate were detected in the laboratory blank. The EPA Five times rule was applied to all target compounds which were found in the blank. Compounds that were found in the sample and in the blank were considered real and not the result of contamination if the levels in the sample are five times or greater than compounds in the method blank. A ten times factor was used for bis-(ethylhexyl) phthalate since it is a common laboratory contaminant. Only the bis-(2-ethylhexyl) phthalate in sample, 498118 was less than ten times the amount found in the blank. Consequently the data qualifier for bis-(2-ethylhexyl) phthalate in sample 498118 was changed from "B" to "UJ" indicating that the amount reported can not be distinguished from the blank level. No additional data qualifiers were necessary for pyrene or fluoranthene since the amounts detected in the sample were greater than five times the concentration detected in the blank.

Surrogates:

Isotopic dilution methods do not require surrogate spike compounds. The isotopically labeled compounds added to the sample prior to extraction as internal standards replace the surrogate compounds normally used and also provide data normally obtained from the matrix spikes. Since these isotopically labeled compounds are added prior to extraction, calculations using these compounds as internal standards automatically corrects for losses of the target analyte during extraction. The data is reported with both the concentration and a percent recovery of the isotopically labeled compounds. The percent recovery reported is the amount of the isotopically labeled internal standard found compared to a reference internal standard, 2,2'-difluorobiphenyl, added just prior to GC/MS analysis. Recovery limits have been established and these have been taken into account by the laboratory when reporting the data.

Matrix Spike and Matrix Spike Duplicate (MS/MSD):

Matrix spikes are not required for isotope dilution methods.

Sample Data:

The "J" qualifier was added to selected compounds which were reported below the lowest calibration standard. Sample 498118 also had an "M" qualifier added to 2-methylnaphthalene due to poor spectral match. The data is acceptable for use with the additional qualifiers.

No Tentatively Identified Compounds were reported with this data due to the interferences caused by the addition of the isotopically labeled compounds.

DATA QUALIFIER DEFINITIONS

U	-	The analyte was not detected at or above the reported value.
J	-	The analyte was positively identified. The associated numerical value is an estimate.
UJ	-	The analyte was not detected at or above the reported estimated value.
D	-	Signifies that the associated value was derived from a secondary dilution.
E	-	This qualifier is used when the concentration of the associated value exceeds the known calibration range.
R	-	The data are unusable for all purposes. The analyte was analyzed for, but the presence of the analyte has not been verified.
M	-	Indicates poor mass spectral match.

Note: If this data is entered into some other format an "N" flag should be added to the compounds reported as tentatively identified compounds. The "N" flag indicates that there is evidence the analyte is present in this sample.

Recd 1/31/90 sm

ANALYTICAL RESOURCES INCORPORATED

Analytical Chemists & Consultants

333 Ninth Ave North
Seattle, Wa 98109-5187
(206) 621-6490

30 January 1990

Stuart Magoon
Department of Ecology
Manchester Laboratory
7411 Beach Drive East
Port Orchard, WA 98366

RE: Sample submitted for Semivolatile (Method 1625) analysis as WDOE City Waterway project (ARI Job #04193).

Dear Stuart:

Please find enclosed the data package for the above referenced job.

Samples arrivied in one shipment on 12/08/89. All samples were received intact No confidential information was received with the samples.

FID Screens
Approximately 1 25 grams wet weight of each sample was extracted with 10 ml of Methylene Chloride. One of the 10 ml of extract was analyzed via FID. Sample chromatograms were compared to a PNA standard analyzed in the same analytical run. No compounds were detected in the samples. Enclosed are the sample's 'FID screen' chromatograms and quantitation reports.

Method 1625

Extraction
Approximately 30.0 grams wet weight of each sample was extracted, with the exception of **Samples 498096** and **498097,** where there was not enough sample available to extract 30.0 grams. In these cases, the entire sample was extracted. It was noted during the extraction procedure that **Sample 498113** smelled strongly of sulfur. Samples were extracted with Methylene Chloride and taken to a final volume of 2.0 ml. One of the 2.0 ml of sample extract was taken through GPC cleanup. An aliquot (approximately 10 grams) of each sample was utilized for percent moisture determination.

GC/MS Analysis
All samples were analyzed via GC/MS Method 1625 on 01/03/90 and 01/04/90. Please refer to the Sample Organic Analysis Data Sheets for surrogate recovery information, matrix interferences, and analyte results. No Matrix Spike/Matrix Spike Duplicate analysis was performed, as none was requested. Enclosed are the chromatograms, quantitation reports, spectra for positive 'hits' and addiitional spectral and chromatographic information for each sample analysis.

If you have any questions regarding this job, please feel free to contact Brian Sue, or me.

Respectfully submitted,

ANALYTICAL RESOURCES, INC.

Michael W. Letourneau
Project Coordinator

Enclosures

cc: File #04193

Particulates- 1-6/90

STATE OF WASHINGTON DEPARTMENT OF ECOLOGY
MANCHESTER ENVIRONMENTAL LABORATORY
P.O. Box 307, Manchester WA 98353

DATA REVIEW
January 7, 1991

Project: City Waterway (ARI project #07004)

Samples: 358108 358111 358117 358118 358119

Laboratory: Analytical Resources Incorporated

By: Greg Perez
Through: Stuart Magoon

CASE SUMMARY

These analyses were reviewed for qualitative and quantitative accuracy, validity and usefulness. Sample analysis was by EPA Method 8270 using capillary columns.

Data Qualifiers

U - The material was analyzed for but was not detected, the associated numerical value is the sample quantitation limit; this means that the compound is not present in the sample at or above the reported level.

J - The associated numerical value is an estimated quantity.

E - This flag is used when the concentration of the associated value exceeds the known calibration range. Reported value is an estimate.

D - Indicates reported value was obtained from a secondary dilution.

UJ - The material was analyzed for but was not detected. The sample quantitation limit is an estimated quantity.

M - Presumptive evidence of the presence of this compound.

BNA FRACTION

Matrix: Sediment

Holding times:

These samples were collected on various dates prior to 8/30/90 and frozen. These samples were extracted and analyzed within holding times.

Surrogates:

Surrogate recoveries for these samples and the method blank are within the QC recovery limits.

Matrix Spike (MS) and Matrix Spike Duplicate (MSD)

MS/MSD recovery and precision data for the spiked sample and for the spiked method blank were acceptable.

Sample Data:

This data is acceptable for use.

Limited sample size made it necessary to elevate the detection limits above those requested in the project plan.

The following changes were made in the reported data:

The spectra for Di-n-octyl phthalate was in my opinion weak. The relative retention time data did provide supporting evidence for the presence of this compound. I have added the qualifier M to the result reported for this compound for samples 358118 and 358119.

Recd 11/14/90 SM

07 November1990

ANALYTICAL RESOURCES INCORPORATED

Analytical
Chemists &
Consultants

333 Ninth Ave. North
Seattle, WA 98109-5187
(206) 621-6490
(206) 621-7523 (FAX)

Stuart Magoon
Washington State Dept. of Ecology
P.O. Box 307
Manchester, WA 98353

RE: Project (City Waterway) - ARI Job # 07004

Dear Stuart,

Please find enclosed the results for the above referenced samples received 09/13/90 for semivolatile analysis.

These ABN samples were extracted using EPA-CLP protocols for analysis of sediments. This protocol uses extraction by sonication, with allowance for GPC cleanup, which was used for this sample set.

These samples were received with a request for low level detection limits. Normal protocol would have been extraction of 30 grams of sample to a final effective volume of two mls. The method would normally be modified to use 100 grams of sample to acheive lower detection limits, but only a small amount of sample was submitted from each station. Therefore the entire sample submitted was extracted and the extract was taken to 0.5 mls after GPC.

Samples were analyzed by GC/MS using DB-5 Megabore 30 meter columns. No unknown analysis was performed per your instructions.

Included here are the results of a spiked method blank that was run with your sample set. This spiked blank is part of an internal QA program.

If you have questions, please feel free to call me at any time.

Sincerely,

ANALYTICAL RESOURCES, INC

Susan D. Rosa Dunnihoo
EPA Project Manager

Enclosures

cc: File 07004

Particulates- 7-12/90

STATE OF WASHINGTON DEPARTMENT OF ECOLOGY
MANCHESTER ENVIRONMENTAL LABORATORY
7411 Beach Drive E., Port Orchard, WA 98366

DATA REVIEW
May 1, 1991

Project: City Waterway Phase II

Samples: 90- 528301, 528302, 528303, 528304, 528305, and 528313

Laboratory: Analytical Resources, Inc.

By: Dickey D. Huntamer
Through: Stuart Magoon

CASE SUMMARY

These analyses were reviewed for qualitative and quantitative accuracy, validity and usefulness. Sample analysis for both matrices used SW846 procedures. Extraction and cleanup methods were consistent with SW 846 Methods for soil samples. Specific methods used and problems incurred during the analysis of these samples are detailed in the case narrative and will not be addressed here. Analytical problems associated with QA/QC will be noted and referenced to the case narrative where appropriate.

There is no need to assimilate the "dilution factor" or "sample wt/vol" into the final values reported; these calculations have already been figured into the reported values. The results are calculated on a dry weight basis.

BNA FRACTION

Method: SW 846 8270

Matrix: Sediment

Holding times

All samples were extracted and analyzed within the recommended holding times.

Surrogates:

Surrogate recoveries for the water samples were acceptable and within QC limits.

Matrix Spike and Matrix Spike Duplicate (MS/MSD):

No Matrix spike and spike duplicate was analyzed with this data set due to the limited sample available and the desire to achieve the lowest practical quantitation limit. The laboratory ran a blank spike with the analysis and the results are included in the data set. The spike consisted of the normal CLP spike compounds and recoveries ranged from 72% to 84%. The Relative Percent Difference (RPD), could not be determined since only one spike was analyzed.

Sample Data:

One Tentatively Identified Compound (TIC), hexadecanoic acid was added to the TIC list. It was found in all of the other samples and reported. The spectral match in sample 528305 was good and the compound should have been reported.

Low quantitation limits were requested on the sample, 100 ug/Kg, but with the exception of 528303 which had the most sample material extracted (15 gm dry weight) at a quantitation limit of 130U ug/Kg, the other samples were a factor of two or more above this level. The reason for the higher quantitation limits is primarily due to the small sample size available for extraction. Despite the higher than requested detection limits many polynuclear aromatic compounds were detected.

Additional "J" qualifiers were added to those compounds which exceeded the Continuing Calibration percent deviation (%D) limit of 25% at the one and five nanogram levels. Ten compounds exceeded the %D limit at the one nanogram level and two compounds were above 25% deviation at the five nanogram level. The data is acceptable for use with the additional qualifiers where appropriate.

DATA QUALIFIER DEFINITIONS

U - The analyte was analyzed for, but was not detected at or above the reported value.

J - The analyte was analyzed for, and positively identified. The associated numerical value is an estimate.

UJ - The analyte was analyzed for, but not detected at or above the reported estimated value.

D - Signifies that the associated value was derived from a secondary dilution.

E - This qualifier is used when the concentration of the associated value exceeds the known calibration range. (ARI uses a "K")

R - The data are unusable for all purposes. The analyte was analyzed for, but the presence of the analyte has not been verified.

M - Indicates poor mass spectral match.

Note: If this data is entered into some other format an "N" flag should be added to the compounds reported as tentatively identified compounds. The "N" flag indicates that there is presumptive evidence that the analyte is present in this sample.

Particulates- 1-6/91

MANCHESTER ENVIRONMENTAL LABORATORY

7411 Beach Drive SE , Port Orchard Washington 98366

CASE NARRATIVE

September 20, 1991

Subject: Commencement Bay

Samples: 91 - 268313, 268320, 268322, 268327, ~~268342, 268345, 268351, 268361, 268364, 268365, 268368, 268374, 268380, 268392, 268394 and 268398~~

Case No. DOE-020P

Officer: Dale Norton

By: Dickey D. Huntamer
Organics Analysis Unit

SEMIVOLATILE ORGANICS

ANALYTICAL METHODS:

The semivolatile soil sample was Soxhlet extracted with acetone following the Manchester modification of the EPA CLP and SW 846 8270 procedure with capillary GC/MS analysis of the sample extracts. Normal QA/QC procedures were performed with the analyses. All data is reported on a wet weight basis except for samples, 268313, 268342, 268345, 268351, 268374, 268380 and 268394. Percent solids for the samples, were 33.8%, 38.4%, 42.7%, 42 8%, 55.5%, 65.1% and 58.5% respectively.

HOLDING TIMES:

All sample and extraction holding times were within the recommended limits.

BLANKS:

Low levels of fluoranthene, pyrene and some phthalates were detected in some of the blanks. The EPA Five times rule was applied to all target compounds which were found in the blank. Compounds that were found in the sample and in the blank were considered real and not the result of contamination if the levels in the sample are greater than or equal to five times the amount of compounds in the associated method blank. Any target compound failing this criteria is given a "UJ" data qualifier.

SURROGATES:

The normal CLP surrogates were added to the sample prior to extraction. Most surrogate spike recoveries were within acceptable QC limits, however eight samples exceeded the recommended limits for 2-Fluorobiphenyl, three exceeded limits for Phenol-d5 and one exceeded limits for 2-Fluorophenol. No data qualifiers were added because of the high surrogate recoveries. The majority of the target compounds detected were Polynuclear Aromatic Hydrocarbons (PAH) and both the Pyrene-d10 and Terphenyl-d14 surrogates which represent this class of compounds were all within acceptable recovery limits. One laboratory blank, WBS1213B, had low surrogate recoveries for all but, Pyrene-d10 and

Terphenyl-d14 indicating that it was concentrated down too low. Consequently all of the that blank data was given the "R" or "REJ" data qualifier. This blank only applied to sample 268394 for re-extraction.

MATRIX SPIKE AND MATRIX SPIKE DUPLICATE:

Matrix spike recoveries and Relative Percent Differences (RPD) were within acceptable QC limits for most of the compounds in the samples. No additional qualifiers were added to the data based on matrix spike recoveries.

SPECIAL ANALYTICAL PROBLEMS:

Almost all of the samples were prescreened by Gas Chromatography/Flame Ionization Detector, GC/FID, prior to analysis to optimize the analytical conditions. Those samples which had a high hydrocarbon/lipid background were diluted and this is reflected in the higher quantitation limits reported for those samples. Insufficient sample precluded percent solid determinations on all of the samples. Where practical, percent solids were taken from the metals and general chemistry aliquots when they corresponded to the organic samples.

DATA QUALIFIER CODES:

U	-	The analyte was not detected at or above the reported value.
J	-	The analyte was positively identified. The associated numerical value is an estimate.
UJ	-	The analyte was not detected at or above the reported estimated result.
REJ	-	The data are unusable for all purposes. (Also R)
EXP	-	The result is equal to the number before EXP times 10 to the power of the number after EXP. As an example 3EXP6 equals 3×10^6.
NAF	-	Not analyzed for.
N	-	For organic analytes there is evidence the analyte is present in this sample.
NJ	-	There is evidence that the analyte is present. The associated numerical result is an estimate.
E	-	This qualifier is used when the concentration of the associated value exceeds the known calibration range.
*	-	The analyte was present in the sample. (Visual Aid to locate detected compound on report sheet.)

Particulates- 6-11/91

MANCHESTER ENVIRONMENTAL LABORATORY

7411 Beach Drive E , Port Orchard Washington 98366

CASE NARRATIVE

March 6, 1992

Subject: Sediment Traps - Commencement Bay

Samples: 91 - 518524 to 518527, - 518533, - 518539, - 518543, - 518546, - 518550 to 518552 - 518555, - 518556, -518560 , -518561, -518567, -518569 and -518572.

Case No. DOE-020Q

Officer: Dale Norton

By: Dickey D. Huntamer
Organics Analysis Unit

SEMIVOLATILE ORGANICS

ANALYTICAL METHODS:

The semivolatile soil samples were Soxhlet extracted with acetone following the Manchester modification of the EPA CLP and SW 846 8270 procedure with capillary GC/MS analysis of the sample extracts. Normal QA/QC procedures were performed with the analyses.

HOLDING TIMES:

The sediment samples were composited samples acquired over a period of time. The samples were stored frozen between collections. After compositing and prior to analysis the samples were kept frozen following Puget Sound Estuary Program guidelines. The samples were thawed, extracted and analyzed within the recommended holding times. No data qualifiers were added due to holding times.

BLANKS:

Low levels of some target compounds were detected in the laboratory blanks. The EPA five times rule was applied to all target compounds which were found in the blank. Compounds that were found in the sample and in the blank were considered real and not the result of contamination if the levels in the sample are greater than or equal to five times the amount of compounds in the associated method blank.

SURROGATES:

The normal CLP surrogates were added to the sample prior to extraction. Most surrogate spike recoveries were within acceptable QC limits except for six samples which each had one out of the recommended limits. All surrogates were out in sample, 518524 due to interferences and problems with spiking. Consequently all the data is reported as "REJ", rejected except for the tentatively identified compounds. Sample data was salvaged by using one of the matrix spikes which serendipitously was not spiked with the target compounds but had the surrogates added. This is reported as a duplicate analysis for 518524.

MATRIX SPIKE AND MATRIX SPIKE DUPLICATE:

Three sets of matrix spikes were analyzed with these samples. These were on samples 518524, 518533 and 518555. One of the matrix spike samples for 518524 was not available due to a problem with spiking. All of the spikes had problems with matrix interferences and the high native concentrations of some target compounds complicated calculating the corrected recoveries. This was particularly true for sample 518533.

SPECIAL ANALYTICAL PROBLEMS:

The requirement for low level analysis resulted in analysis of the smallest possible extract volume. This caused rapid deterioration of the capillary column resulting in frequent column reconditioning and some column changes. Most of the samples exhibited large "humps" of eluting material loosely referred to as "biogenic yuck", which appeared to consist of mixtures of fatty acid, steroids, assorted biological molecules along with the usual petroleum hydrocarbons. The tentatively identified compounds reported consisted primarily of unidentifiable hydrocarbons or compounds along with sterols and fatty acids. In sample 518543 some possible resin acids were also detected.

A Canadian reference sample was analyzed in duplicate with this sample set. 518572 and 518572D. These were analyzed as blind samples without having the "true" values and we would appreciate receiving a copy of the actual values for comparison.

The data is acceptable for use as qualified.

DATA QUALIFIER CODES:

U	-	The analyte was not detected at or above the reported value.
J	-	The analyte was positively identified. The associated numerical value is an estimate.
UJ	-	The analyte was not detected at or above the reported estimated result.
REJ	-	The data are unusable for all purposes.
EXP	-	The result is equal to the number before EXP times 10 to the power of the number after EXP. As an example 3EXP6 equals 3×10^6.
NAF	-	Not analyzed for.
N	-	For organic analytes there is evidence the analyte is present in this sample.
NJ	-	There is evidence that the analyte is present. The associated numerical result is an estimate.
E	-	This qualifier is used when the concentration of the associated value exceeds the known calibration range.
*	-	The analyte was present in the sample. (Visual Aid to locate detected compound on report sheet.)

Particulates- 12/91-5/92

MANCHESTER ENVIRONMENTAL LABORATORY

7411 Beach Drive E , Port Orchard Washington 98366

CASE NARRATIVE

October 8, 1992

Subject: Commencement Bay Sediment Traps

Samples: 92 - 268426 to -268430, -268433, -268436, -268444, -268452, -268463 to 268467, -268494 to -268498

Case No. DOE-370Y

Officer: Dale Norton

By: Dickey D. Huntamer
Organics Analysis Unit

SEMIVOLATILE ORGANICS

ANALYTICAL METHODS:

The semivolatile soil samples were Soxhlet extracted with acetone following the Manchester modification of the EPA SW 846 8270 procedure with capillary GC/MS analysis of the sample extracts. Normal QA/QC procedures were performed with the analyses.

HOLDING TIMES:

All sample and extraction holding times were within the recommended limits.

BLANKS:

Low levels of some target compounds were detected in the laboratory blanks. The EPA five times rule was applied to all target compounds which were found in the blank. Compounds that were found in the sample and in the blank were considered real and not the result of contamination if the levels in the sample are greater than or equal to five times the amount of compounds in the associated method blank.

SURROGATES:

The normal surrogates compounds were added to the sample prior to extraction. Only three surrogate spike recoveries were outside acceptable QC limits all of the others were acceptable. Four samples, blanks BS2189 and BS2189D along with samples 92-268396 and -268397 (Canadian reference material HR-6), under went the silica gel polynuclear aromatic hydrocarbon (PAH) clean-up procedure. Consequently only surrogate recoveries for 2-fluorobiphenyl, d10-pyrene and d14-terphenyl are valid.

MATRIX SPIKE AND MATRIX SPIKE DUPLICATE:

Matrix spike recoveries and Relative Percent Differences (RPD) were acceptable for most of the Contract Laboratory Program (CLP) check compounds except for phenanthrene and pyrene. Both of these compounds were found in the sample at relatively high levels and correction of the matrix spikes could not be made. Spike recoveries for most of the remaining non-CLP compounds were also affected by the high native concentrations and could not be calculated.

SPECIAL ANALYTICAL PROBLEMS:

No special analytical problems were encountered in the semivolatile analyses. The HR-6 reference material samples, -268396 and -97 were mistakenly given the silica gel clean-up procedure. Since HR-6 is primarily certified for the PAH compounds this should not be a major problem and the results should still be valid.

A smaller sample size than normal, five to 10 grams, was used in the extraction. The small sample size was compensated for by concentrating to a lower volume for injection. This resulted in similar sample quantitation limits compared to previous analyses. Analysis and review at these low levels was complicated by the large amounts of interfering biogenic material which affected the chromatography.

In all samples except, 268427, 268433, 268463 and 268465, results for benzo(b)fluoranthene and benzo(k)fluoranthene could not resolved. Consequently the results were reported as benzo(b) fluoranthene but includes benzo(k)fluoranthene as well and the results for benzo(k)fluoranthene were flagged as not detected, "U".

Due to interferences in the samples several internal standard area counts were outside the acceptable limits. Those samples and compounds affected by this were qualified by adding the "J" qualifier.

DATA QUALIFIER CODES:

U	-	The analyte was not detected at or above the reported value.
J	-	The analyte was positively identified. The associated numerical value is an estimate.
UJ	-	The analyte was not detected at or above the reported estimated result.
REJ	-	The data are unusable for all purposes.
EXP	-	The result is equal to the number before EXP times 10 to the power of the number after EXP. As an example 3EXP6 equals 3×10^6.
NAF	-	Not analyzed for.
N	-	For organic analytes there is evidence the analyte is present in this sample
NJ	-	There is evidence that the analyte is present. The associated numerical result is an estimate.
E	-	This qualifier is used when the concentration of the associated value exceeds the known calibration range.
*	-	The analyte was present in the sample. (Visual Aid to locate detected compound on report sheet.)

Particulates- 5-11/92

MANCHESTER ENVIRONMENTAL LABORATORY

7411 Beach Drive E , Port Orchard Washington 98366

CASE NARRATIVE

March 31, 1993

Subject: Commencement Bay

Samples: 92 - 498272 to -498277, -498279, -498288 -498303 to -498305, -498307, -498331 to -498335

Case No. DOE-555Y

Officer: Dale Norton

By: Dickey D. Huntamer
Organics Analysis Unit

SEMIVOLATILE ORGANICS

ANALYTICAL METHODS:

The semivolatile soil samples were Soxhlet extracted with acetone following the Manchester modification of the EPA SW 846 8270 procedure with capillary GC/MS analysis of the sample extracts The sample extracts were cleaned up prior to analysis using silica gel. By eluting with various mixtures of solvents the semivolatile target compounds could be recovered. Normal QA/QC procedures were performed with the analyses. A pair of Canadian reference materials (HS-6) were also analyzed with the samples.

HOLDING TIMES:

The samples were stored frozen until sample preparation following Puget Sound Estuary Program guidelines. All sample and extraction holding times were within the recommended limits.

BLANKS:

Low levels of some target compounds were detected in the laboratory blanks. The EPA five times rule was applied to all target compounds which were found in the blank Compounds that were found in the sample and in the blank were considered real and not the result of contamination if the levels in the sample are greater than or equal to five times the amount of compounds in the associated method blank

SURROGATES:

The normal surrogates compounds were added to the sample prior to extraction. All surrogate spike recoveries were within acceptable QC limits.

MATRIX SPIKE AND MATRIX SPIKE DUPLICATE:

Matrix spike recoveries for the EPA Contract Laboratory Program (CLP) compounds were within acceptable limits. Eight other non-CLP compounds had less than 50% recovery and the results for those compounds in the matrix sample, 92-498303 were qualified by adding "J". The base compounds were not part of the spiking mixture and therefore are reported as no analyte found (NAF). One compound, Hexachloroethane had low recoveries < 4%, and also was reported as NAF.

SPECIAL ANALYTICAL PROBLEMS:

No special analytical problems were encountered in the semivolatile analyses. The silica gel clean-up for semivolatiles worked well, eliminating much of the interferences caused by the presence of fats and lipids. This allowed the samples to be analyzed at a smaller volume and improved chromatography which resulted in better quantitation limits.

The Canadian reference material (HS-6) results are reported as sample 93498335 SRM1 and SRM2.

DATA QUALIFIER CODES:

U	-	The analyte was not detected at or above the reported value
J	-	The analyte was positively identified. The associated numerical value is an estimate.
UJ	-	The analyte was not detected at or above the reported estimated result.
REJ	-	The data are unusable for all purposes.
EXP	-	The result is equal to the number before EXP times 10 to the power of the number after EXP. As an example 3EXP6 equals 3×10^6
NAF	-	Not analyzed for
N	-	For organic analytes there is evidence the analyte is present in this sample.
NJ	-	There is evidence that the analyte is present. The associated numerical result is an estimate.
E	-	This qualifier is used when the concentration of the associated value exceeds the known calibration range.
bold	-	The analyte was present in the sample. (Visual Aid to locate detected compound on report sheet.)

CN_CBAY6.DOC

Case Narratives for Butyltins Analysis

Particulates- 1-6/90

MANCHESTER ENVIRONMENTAL LABORATORY

7411 Beach Drive S E. Port Orchard, WA 98366

CASE NARRATIVE

December 17 , 1990

Subject: City Waterway Sediment Monitoring

Samples: 90 -358117 - 358118

Case No.: DOE-799K

Officer: Dale Norton

By: Dickey D. Huntamer DDH
Keith Solberg K.S.
Organic Analysis Unit

ORGANOTINS

ANALYTICAL METHODS:

The samples were extracted following the methods given in Puget Sound Estuary Program (PSEP) "Recommended Guidelines for Measuring Organic Compounds in Puget Sound Sediment and Tissue Samples" Recommended Methods for Organotin Compounds. The samples were soxhlet extracted using acetone and tropolone, 0.2% by weight, solvent exchanged to hexane and dried using sodium sulfate. The organotin compounds were hexylated using the Grignard reaction given in Krone et al (1989) including the subsequent silica gel/alumina cleanup. Analysis was done by capillary Gas Chromatography using a Flame Photometric Detector (FPD). All data is reported on a wet weight basis.

HOLDING TIMES:

The samples were stored frozen following PSEP Guidelines until extraction. After extraction all samples were analyzed within the recommended 40 day extract time.

BLANKS:

No significant blank contamination was detected.

SURROGATES:

Recovery of the surrogate spike , Tripropyltin, ranged from 28.7% to 82.5%. No surrogate recovery QC limits have been established for this method.

MATRIX SPIKE AND MATRIX SPIKE :

Insufficient sample was available to run a matrix spike and matrix spike duplicate (MS/MSD) on the samples themselves, however an MS/MSD was analyzed using matrix material from the Sequim Bay Reference Material. No spike recovery QC limits have been established for Organotins at this time. The Relative Percent Differences (RPD) for the matrix spikes were:

13.6% Tetrabutyltin
64.8% Tributyltin
13.1% Dibutyltin
17.3% Monobutyltin
49.5% Tripropyltin (surrogate).

SPECIAL ANALYTICAL PROBLEMS:

No special analytical problems were encountered in the analysis with the exception of high sulfur content in the sample extracts. The sulfur was removed by treatment with elemental mercury prior to derivitization (hexylation) with the Grignard reagent.

Three additional samples were analyzed with the sediment samples. These were Sequim Bay Reference Sediment which presumably was spiked with 100 ng/gm (100ug/Kg) wet weight of tributyltin. No value for tributyltin has been established for the Sequim Bay Reference Sediment so the accuracy of the analysis cannot be determined but the data does give an idea of the precision as represented by the triplicate analysis of tributyltin.

35SQIA	24	ug/Kg
35SQIB	18	ug/Kg
35SQIC	23	ug/Kg

Some dibutyltin and monobutyltin was also detected in the Sequim bay samples.

DATA QUALIFIER CODES:

U - The material was analyzed for, but was not detected. The associated numerical value is the sample quantitation limit.

J - The associated numerical value is an estimated quantity.

R - The data are unusable (compound may or may not be present). Resampling and reanalysis is necessary for verification.

NAR No Analytical Result.

NJ - Presumptive evidence of the presence of the compound at an estimated quantity.

Krone, C. A. , D. W. Brown, D. G. Burrows, R. G. Bogar, S.-L. Chan and U. Varanasi. 1989. A method for analysis of butyltin species and the measurement of butyltins in sediment and English sole livers from Puget Sound. Mar. environ. Res. 27:1-18.

Particulates- 7-12/90

MANCHESTER ENVIRONMENTAL LABORATORY

7411 Beach Drive S.E. Port Orchard, WA 98366

CASE NARRATIVE

February 15, 1991

Subject: City Waterway Sediment Monitoring II

Samples: 90 -528301 - 528305, 528313

Case No.: DOE-799L

Officer: Dale Norton

By: Dickey D. Huntamer
Keith Solberg
Organic Analysis Unit

ORGANOTINS

ANALYTICAL METHODS:

The samples were extracted following the methods given in Puget Sound Estuary Program (PSEP) "Recommended Guidelines for Measuring Organic Compounds in Puget Sound Sediment and Tissue Samples" Recommended Methods for Organotin Compounds. The samples were soxhlet extracted using acetone and tropolone, 0.2% by weight, solvent exchanged to hexane and dried using sodium sulfate. The organotin compounds were hexylated using the Grignard reaction given in Krone et al (1989) including the subsequent silica gel/alumina cleanup. Analysis was done by capillary Gas Chromatography using a Flame Photometric Detector (FPD).

HOLDING TIMES:

The samples were stored frozen following PSEP Guidelines until extraction. Samples were extracted within 10 days of sample receipt and were analyzed within the recommended 40 day extract time.

BLANKS:

No significant blank contamination was detected.

SURROGATES:

Recovery of the surrogate spike , Tripropyltin, ranged from 45.3% to 71.7% except for sample 90-528313 which bumped during sample concentration and was lost. No surrogate recovery QC limits have been established for this method.

MATRIX SPIKE AND MATRIX SPIKE :

Insufficient sample was available to run a matrix spike and matrix spike duplicate (MS/MSD) on the samples themselves, however an MS/MSD was analyzed using matrix material from the Sequim Bay Reference Material. No spike recovery QC limits have been established for Organotins at this time. The Relative Percent Differences (RPD) for the matrix spikes were:

7.5%	Tetrabutyltin
36.7%	Tributyltin
4.8%	Dibutyltin
NAR	Monobutyltin
16.6%	Tripropyltin (surrogate).

SPECIAL ANALYTICAL PROBLEMS:

Samples 90-528302, 528304, and 528305 are reported on a wet weight basis due to insufficient sample to determine percent solids. Two samples , 528304 and 528313, bumped during sample concentration resulting in sample loss. For sample 528304 the losses were relatively insignificant based on surrogate recovery but no surrogate was recovered in sample 528313 indicating severe sample attrition and no organotin compounds were detected. The Not Detected (ND) qualifier could be replaced by the Laboratory Accident (LAC) qualifier in the data.

Monobutyltin has poor recoveries due to the difficulty in extracting this compound from the sample. This skews the results because the small response factor can multiply any errors in the analysis as is evident by the 315% recovery for the matrix spike duplicate and the non detection, ND, for the first matrix spike.

No other analytical problems were encountered in the analysis with the exception of high sulfur content in the sample extracts. The sulfur was removed by treatment with elemental mercury prior to derivitization (hexylation) with the Grignard reagent.

One additional sample was analyzed with the sediment samples. This was a Sequim Bay Reference Sediment which presumably was spiked with 100 ng/gm (100ug/Kg) wet weight of tributyltin. No value for tributyltin has been established for the Sequim Bay Reference Sediment so the accuracy of the analysis cannot be determined.

90-528314	SQ1	36	ug/Kg	(wet weight)
		51	ug/Kg	(dry weight)

DATA QUALIFIER CODES:

U - The material was analyzed for, but was not detected. The associated numerical value is the sample quantitation limit.

J - The associated numerical value is an estimated quantity.

R - The data are unusable (compound may or may not be present). Resampling and reanalysis is necessary for verification.

NAR No Analytical Result.

NJ - Presumptive evidence of the presence of the compound at an estimated quantity.

ND - Not Detected

LAC - Laboratory Accident

Krone, C. A., D. W. Brown, D. G. Burrows, R. G. Bogar, S.-L. Chan and U. Varanasi. 1989. A method for analysis of butyltin species and the measurement of butyltins in sediment and English sole livers from Puget Sound. Mar. environ. Res. 27:1-18.

Bottom sediment- 1/91

MANCHESTER ENVIRONMENTAL LABORATORY

7411 Beach Drive SE , Port Orchard Washington 98366

CASE NARRATIVE

September 17, 1991

Subject: Commencement Bay

Samples: 91 -048223 to 048228

Case No. DOE-020N

Officer: Dale Norton

By: Dickey D. Huntamer
Organics Analysis Unit

ORGANOTINS

ANALYTICAL METHODS:

The samples were extracted following the methods given in Puget Sound Estuary Program (PSEP) "Recommended Guidelines for Measuring Organic Compounds in Puget Sound Sediment and Tissue Samples" Recommended Methods for Organotin Compounds. The samples were Soxhlet extracted using acetone and tropolone, 0.2% by weight, solvent exchanged to hexane and dried using sodium sulfate. The organotin compounds were hexylated using the Grignard reaction given in Krone et al (1989) including the subsequent silica gel/alumina cleanup. Analysis was done by capillary Gas Chromatography using a Flame Photometric Detector (FPD).

HOLDING TIMES:

The samples were stored frozen following PSEP Guidelines until extraction. No recommended holding times have been established by EPA for this analysis method.

BLANKS:

No significant blank contamination was detected.

SURROGATES:

Recovery of the surrogate spike , Tripropyltin, ranged from 22.4% to 79.8%. No surrogate recovery limits have been established for tripropyltin at this time.

MATRIX SPIKE AND MATRIX SPIKE :

A matrix spike and matrix spike duplicate (MS/MSD) was analyzed using sample 91-048225. No results are available for tetrabutyltin. Results for tributyltin and dibutyltin ranged from 54% to 158% recoveries. No spike recovery QC limits have been established for Organotins at this time. The Relative Percent Differences (RPD) for the matrix spikes were:

NAR*	Tetrabutyltin
34%	Tributyltin
44%	Dibutyltin
104%	Monobutyltin
36%	Tripropyltin (surrogate).

* Not Added to Spike

SPECIAL ANALYTICAL PROBLEMS:

All samples are reported on a dry weight basis. Monobutyltin has poor recoveries due to the difficulty in extracting this compound from the sample. This is reflected in the wide variation in matrix spike recoveries and the large RPD.

No other analytical problems were encountered in the analysis with the exception of high sulfur content in the sample extracts. The sulfur was removed by treatment with elemental mercury prior to derivitization (hexylation) with the Grignard reagent.

One additional sample was analyzed with the sediment samples. This was a Sequim Bay Reference Sediment which presumably was spiked with 100 ng/gm (100ug/Kg) wet weight of tributyltin. No value for tributyltin has been established for the Sequim Bay Reference Sediment so the accuracy of the analysis cannot be determined.

91 -048204	SQ1	12.2	ug/Kg	(wet weight)
		20	ug/Kg	(dry weight)

DATA QUALIFIER CODES:

U	-	The analyte was not detected at or above the reported value.
J	-	The analyte was positively identified. The associated numerical value is an estimate.
UJ	-	The analyte was not detected at or above the reported estimated result.
REJ	-	The data are unusable for all purposes.
EXP	-	The result is equal to the number before EXP times 10 to the power of the number after EXP. As an example 3EXP6 equals 3×10^6.
NAF	-	Not analyzed for.
N	-	For organic analytes there is evidence the analyte is present in this sample.
NJ	-	There is evidence that the analyte is present. The associated numerical result is an estimate.
E	-	This qualifier is used when the concentration of the associated value exceeds the known calibration range.
*	-	The analyte was present in the sample. (Visual Aid to locate detected compound on report sheet.)

Particulates- 1-6/91

MANCHESTER ENVIRONMENTAL LABORATORY

7411 Beach Drive SE , Port Orchard Washington 98366

CASE NARRATIVE

October 7, 1991

Subject: Commencement Bay

Samples: 91- 268320, 268322 and 268323

Case No. DOE-020P

Officer: Dale Norton

By: Dickey D. Huntamer
Keith Solberg
Organics Analysis Unit

TRIBUTYL TINS

ANALYTICAL METHODS:

The samples were extracted following the methods given in Puget Sound Estuary Program (PSEP) "Recommended Guidelines for Measuring Organic Compounds in Puget Sound Sediment and Tissue Samples" Recommended Methods for Organotin Compounds. The samples were soxhlet extracted using acetone and tropolone, 0.2% by weight, solvent exchanged to hexane and dried using sodium sulfate. The organotin compounds were hexylated using the Grignard reaction given in Krone et al (1989) including the silica gel/alumina cleanup. Analysis was done by capillary Gas Chromatography using a Flame Photometric Detector (FPD). Percent solids was not available so all results are on a weight weight basis.

HOLDING TIMES:

The samples were stored frozen following PSEP Guidelines until extraction. After extraction all samples were analyzed within the recommended 40 day extract time.

BLANKS:

One of the laboratory blanks (BS1240D) was lost in a lab accident (LAC) but the primary blank BS1240 was okay. No significant blank contamination was detected.

SURROGATES:

Recovery of the surrogate spike, Tripropyltin, was 61% for the blank and 120% for sample 268320 but suffered from chromatographic interference in samples 268322 and 268323. A second compound tetrapropyltin was added to see if it could serve as an internal standard or alternate surrogate for the method. Unfortunately the initial spiking level was too low and it also appears to be subject to the same interferences as the tripropyltin surrogate. Recoveries for tetrapropyltin were 44% in the blank and 116% in sample 268322. The other surrogate recoveries could not be determined due to interference from sulfur despite performing sulfur cleanup procedures prior to analysis. No surrogate recovery QC limits have been established for this method.

MATRIX SPIKE AND MATRIX SPIKE :

Both the matrix spike and spike duplicate had significant chromatographic interference. Consequently recoveries for only dibutyltin and monobutyltin for one matrix spike at 68% and 36% respectively are reported. Recoveries of the other analytes in the matrix spikes could not be determined using the Flame Photometric Detector primarily due to sulfur interference. No spike recovery QC limits have been established for Organotins at this time. The Relative Percent Differences (RPD) for the matrix spikes could not be established.

SPECIAL ANALYTICAL PROBLEMS:

The principle analytical problems encountered were directly related to the chromatographic interferences due to sulfur. Mercury treatment was used in an attempt to remove as much sulfur as possible but it appears not to have been 100% successful. Either better sulfur cleanup techniques or changing to a more discriminatory detector may be necessary to eliminate this problem.

One additional sample was analyzed with the sediment samples. This was a Sequim Bay Reference Sediment which presumably was spiked with 100 ng/gm (100ug/Kg) wet weight of tributyltin. No value for tributyltin has been established for the Sequim Bay Reference Sediment so the accuracy of the analysis cannot be determined.

SQI	28	ug/Kg (wet weight)	Tributyltin

Some dibutyltin (5.4 ug/Kg) was also detected in the Sequim bay samples.

DATA QUALIFIER CODES:

U	-	The analyte was not detected at or above the reported value.
J	-	The analyte was positively identified. The associated numerical value is an estimate.
UJ	-	The analyte was not detected at or above the reported estimated result.
REJ	-	The data are unusable for all purposes.
EXP	-	The result is equal to the number before EXP times 10 to the power of the number after EXP. As an example 3EXP6 equals 3×10^6.
NAF	-	Not analyzed for.
N	-	For organic analytes there is evidence the analyte is present in this sample.
NJ	-	There is evidence that the analyte is present. The associated numerical result is an estimate.
E	-	This qualifier is used when the concentration of the associated value exceeds the known calibration range.
*	-	The analyte was present in the sample. (Visual Aid to locate detected compound on report sheet.)

Particulates- 6-11/91

MANCHESTER ENVIRONMENTAL LABORATORY

7411 Beach Drive SE , Port Orchard Washington 98366

CASE NARRATIVE

February 10, 1992

Subject: Sediment Traps - Commencement Bay

Samples: 91- 518524, - 518525, - 518526 and - 518527

Case No. DOE-020Q

Officer: Dale Norton

By: Dickey D. Huntamer
Keith Solberg
Organics Analysis Unit

TRIBUTYLTINS

ANALYTICAL METHODS:

The samples were extracted following the methods given in Puget Sound Estuary Program (PSEP) "Recommended Guidelines for Measuring Organic Compounds in Puget Sound Sediment and Tissue Samples" Recommended Methods for Organotin Compounds. The samples were Soxhlet extracted using acetone and tropolone, 0.2% by weight, solvent exchanged to hexane and dried using sodium sulfate. The organotin compounds were hexylated using the Grignard reaction given in Krone et al (1989) including the silica gel/alumina cleanup. Analysis was done by capillary Gas Chromatography using a Flame Photometric Detector (FPD). All results are reported on a dry weight basis.

HOLDING TIMES:

The samples were stored frozen following PSEP Guidelines until extraction. After extraction all samples were analyzed within the recommended 40 day extract time.

BLANKS:

No significant blank contamination was detected.

SURROGATES:

Surrogate spike recoveries for Tripropyltin ranged from 17% to 120%. A second compound tetrapropyltin was added as a possible alternate surrogate or potential internal standard for the method. Recoveries for tetrapropyltin ranged from 16% to 140%. No surrogate recovery QC limits have been established for this method.

MATRIX SPIKE AND MATRIX SPIKE :

Spike recoveries for tetrabutyltin were 20% and 39%, tributyltin 140% and dibutyltin 140% and 150%. The Relative Percent Differences (RPD) was 64% for tetrabutyltin, 0% for tributyltin and 6.9% for dibutyltin. No spike recovery or RPD QC limits have been established for the organotins at this time.

SPECIAL ANALYTICAL PROBLEMS:

The principle analytical problems encountered were directly related to the chromatographic interferences due to sulfur. Mercury treatment was used in an attempt to remove as much sulfur as possible but it is not always 100% successful. Either better sulfur cleanup techniques or changing to a more discriminatory detector may be necessary to eliminate this problem.

One additional sample was analyzed with the sediment samples. This was a Sequim Bay Reference Sediment which presumably was spiked with 100 ng/gm (100ug/Kg) wet weight of tributyltin. No value for tributyltin has been established for the Sequim Bay Reference Sediment so the accuracy of the analysis cannot be determined.

SQI	36	ug/Kg (dry weight)	Tributyltin (solids = 66.6%)

DATA QUALIFIER CODES:

U	-	The analyte was not detected at or above the reported value.
J	-	The analyte was positively identified. The associated numerical value is an estimate.
UJ	-	The analyte was not detected at or above the reported estimated result.
REJ	-	The data are unusable for all purposes.
EXP	-	The result is equal to the number before EXP times 10 to the power of the number after EXP. As an example 3EXP6 equals 3×10^6.
NAF	-	Not analyzed for.
N	-	For organic analytes there is evidence the analyte is present in this sample.
NJ	-	There is evidence that the analyte is present. The associated numerical result is an estimate.
E	-	This qualifier is used when the concentration of the associated value exceeds the known calibration range.
*	-	The analyte was present in the sample. (Visual Aid to locate detected compound on report sheet.)

Particulates- 12/91-5/92

MANCHESTER ENVIRONMENTAL LABORATORY

7411 Beach Drive E , Port Orchard Washington 98366

CASE NARRATIVE

September 24, 1992

Subject: Commencement Bay Sediment Traps

Samples: 92 - 268426 to -268429 and -268433.

Case No. DOE-370Y

Officer: Dale Norton

By: Dickey D. Huntamer
Organics Analysis Unit

TRIBUTYLTINS

ANALYTICAL METHODS:

The samples were extracted following the methods given in Puget Sound Estuary Program (PSEP) "Recommended Guidelines for Measuring Organic Compounds in Puget Sound Sediment and Tissue Samples" Recommended Methods for Organotin Compounds. The samples were Soxhlet extracted using acetone and tropolone, 0.2% by weight, solvent exchanged to hexane and dried using sodium sulfate. The organotin compounds were hexylated using the Grignard reaction given in Krone et al (1989) including the silica gel/alumina cleanup. Analysis was done by capillary Gas Chromatography using the Atomic Emission Detector due to problems with the Flame Photometric Detector (FPD). Percent solids was not available when the results were calculated for sample -268428 so results are on a weight basis. The percent solids as determined for the semivolatile analysis was 43.8% for sample 268428. All other samples are reported on a dry weight basis.

HOLDING TIMES:

The samples were stored frozen following PSEP Guidelines until extraction. After extraction all samples were analyzed within the recommended 40 day extract holding time.

BLANKS:

No target compounds were detected in the blank.

SURROGATES:

Recovery of the surrogate spike, Tripropyltin, was 79% and 57% for the blanks and ranged from 190% to 340% for the samples. The Sequim Bay reference sample surrogate recovery was 47% and the matrix spikes on sample 268433 were 370% and 380%. Although no surrogate recovery limits have been established for this method the high surrogate recoveries in the samples and matrix spikes introduces an unknown quantity into the analysis. Consequently all positive results for samples 268426 to 268429 and 268433 have been qualified with the "J" flag.

Particulates- 5-11/92

MANCHESTER ENVIRONMENTAL LABORATORY

7411 Beach Drive E , Port Orchard Washington 98366

CASE NARRATIVE

April 26, 1993

Subject: Commencement Bay Sediment Traps

Samples: 92 - 498331 to -498335

Case No. 356

Officer: Dale Norton

By: Dickey D. Huntamer
Organics Analysis Unit

TRIBUTYL TINS

ANALYTICAL METHODS:

The samples were extracted following the methods given in Puget Sound Estuary Program (PSEP) "Recommended Guidelines for Measuring Organic Compounds in Puget Sound Sediment and Tissue Samples" Recommended Methods for Organotin Compounds. The samples were Soxhlet extracted using acetone and tropolone, 0.2% by weight, solvent exchanged to hexane and dried using sodium sulfate. The organotin compounds were hexylated using the Grignard reaction given in Krone et al (1989) including the silica gel cleanup. Analysis was done by capillary Gas Chromatography using an Ion Trap Detector (ITD). Percent solids was factored into the calculations and results are reported on a dry weight basis.

HOLDING TIMES:

The samples were stored frozen following PSEP Guidelines until extraction. After extraction all samples were analyzed within the recommended 40 day extract time.

BLANKS:

No target compounds were detected in the laboratory blanks.

SURROGATES:

Recovery of the surrogate spike, Tripropyltin, ranged from 103% to 178%. No surrogate recovery QC limits have been established for this method.

MATRIX SPIKE AND MATRIX SPIKE :

The matrix spike recoveries for tributyltin were 157% and 178% with a Relative Percent Differences (RPD) of 13%. The other compounds, tetrabutyl tin, dibutyl tin and monobutyltin were not detected in the matrix spikes and consequently the results are listed as no analyte found (NAF). No spike recovery QC limits have been established for Organotins at this time.

MATRIX SPIKE AND MATRIX SPIKE :

Matrix spike recoveries for tributyltin were 140% and 110%. The Relative Percent Differences (RPD) for the matrix spikes was 24%. No spike recovery or RPD QC limits have been established for organotins at this time. The high surrogate recoveries did not appear to affect the spike recoveries. They were not significantly higher and were within the acceptable range of 50% to 150%.

SPECIAL ANALYTICAL PROBLEMS:

These samples were analyzed on the Atomic Emission Detector (AED) instead of the Flame Photometric Detector (FPD) normally used when it was discovered that the FPD was not operating properly. The AED had been previously tested as an alternate method for tributyltins and had performed satisfactorily. The problem may not be with the detector used but may be associated with activation of the injection port by carry over of the reagents used in the analysis. All of the samples experienced increases in concentration with each succeeding injection. To minimize this effect alternate standards and samples were injected and the organotin results for each sample were calculated off the previous standard. This appears to have compensated for the increases observed with each injection for the target compounds but the tripropyltin surrogate was not part of the standard used. Consequently tripropyltin concentrations were not compensated, as were the target compounds, leading to the high surrogate recoveries.

One additional sample was analyzed with the sediment samples. This was a Bay Reference Sediment which presumably was spiked with 100 ng/gm (100 ug/Kg) wet weight of tributyltin. No value for tributyltin has been established for the Sequim Bay Reference Sediment so the accuracy of the analysis cannot be determined.

SQI	120	ug/Kg (wet weight)	Tributyltin
	62	" " " "	Dibutyltin

DATA QUALIFIER CODES:

U	-	The analyte was not detected at or above the reported value.
J	-	The analyte was positively identified. The associated numerical value is an estimate.
UJ	-	The analyte was not detected at or above the reported estimated result.
REJ	-	The data are unusable for all purposes.
EXP	-	The result is equal to the number before EXP times 10 to the power of the number after EXP. As an example 3EXP6 equals 3×10^6.
NAF	-	Not analyzed for.
N	-	For organic analytes there is evidence the analyte is present in this sample.
NJ	-	There is evidence that the analyte is present. The associated numerical result is an estimate.
E	-	This qualifier is used when the concentration of the associated value exceeds the known calibration range.
*	-	The analyte was present in the sample. (Visual Aid to locate detected compound on report sheet.)

ANALYTICAL COMMENTS:

In past analyses using the Flame Photometric Detector (FPD), the principle analytical problem was directly related to chromatographic interferences due to sulfur. These samples were treated with Mercury and analyzed on the ITD mass spectral detector. This eliminated most of the sulfur problems but was not as sensitive as the FPD. Chromatographic interferences were still a problem on the ITD but less so than with the FPD due to the ability to look at specific masses.

The performance of the tetrabutyltin, dibutyltin and monobutyltin was poor particularly in the spike samples where these other tins were not recovered but tributyltin and tripropyl (surrogate) had good recoveries. This could be related to steric hindrance during derivitization with the Grignard reagent and/or due to less reactivity toward the Grignard derivitization depending on substitution. Consequently results for the tetra-, di-, and mono- tins were qualified with "J" in the samples.

Two additional sample was analyzed with the sediment samples. This was a Sequim Bay Reference Sediment which presumably was spiked with 100 ng/gm (100 ug/Kg) wet weight of tributyltin. No value for tributyltin has been established for the Sequim Bay Reference Sediment so the accuracy of the analysis cannot be determined. (Reported on a dry weight basis.)

92-498335	SRM1	SQI	87	ug/Kg	(59.9% solids)	Tributyltin
"	SRM2	SQID	45	"	"	"

Some dibutyltin (15 J ug/Kg) and tetrabutyltin (127 J ug/Kg) was also detected in the Sequim bay (SRM2) sample but not in the SRM1 sample.

DATA QUALIFIER CODES:

U	-	The analyte was not detected at or above the reported value.
J	-	The analyte was positively identified. The associated numerical value is an estimate.
UJ	-	The analyte was not detected at or above the reported estimated result.
REJ	-	The data are unusable for all purposes.
EXP	-	The result is equal to the number before EXP times 10 to the power of the number after EXP. As an example 3EXP6 equals 3×10^6.
NAF	-	Not analyzed for.
N	-	For organic analytes there is evidence the analyte is present in this sample.
NJ	-	There is evidence that the analyte is present. The associated numerical result is an estimate.
E	-	This qualifier is used when the concentration of the associated value exceeds the known calibration range.
bold	-	The analyte was present in the sample. (Visual Aid to locate detected compound on report sheet.)

Appendix C: Water Column Profile Data

Table C1: Summary of water column profile data for Thea Foss Waterway collected August 1989 to June 1991

Location	Mouth			Central		
Station No	FP-3			FP-2		
Level	Surface	Mid	Bottom	Surface	Mid	Bottom
			August 30, 1989			
Sample No 35-	7209	7210	7211/12*	7213	7214	7215
Depth (ft)	0	16	28	0	12	22
Temp (°C)	14.6	12.6	12.4	14.4	12.9	12.5
Salinity (o/oo)	26	32	32	25	32	32
TSS (mg/l)	3	2	10	4	6	14
			December 5, 1989			
Sample No 49-	8119	8120	8121/22*	8123	8124	8125
Depth (ft)	0	20	40	0	26	35
Temp (°C)	10.5	10.9	10.9	10.5	10.9	10.9
Salinity (o/oo)	16	32	32	18	31	32
TSS (mg/l)	8	12	10	10	13	7
			December 12, 1990			
Sample No 03-	7690	7691	7692/93*	7694	7695	7696
Depth (ft)	0	19	36	0	16	32
Temp (°C)	8.3	9.5	9.5	8.1	9.5	9.5
Salinity (o/oo)	20	30	30	17	31	30
TSS (mg/l)	7	2	3	4	6	10
			April 18, 1990			
Sample No 16-	8020	8021	8022/23*	8024	8025	8026
Depth (ft)	0	17	35	0	14	26
Temp (°C)	11.0	9 3	9 0	11.6	9 3	9 2
Salinity (o/oo)	25.4	27 9	28 6	24	28 1	28 3
TSS (mg/l)	3	4	4	8	9	7
			July 7, 1990			
Sample No 27-	8050	8051	8052/53*	8054	8055	8056
Depth (ft)	0	19	36	0	15	29
Temp (°C)	13.8	11.4	11 1	13 4	11 8	11 4
Salinity (o/oo)	24.0	29.0	30 0	26 3	29 0	29.0
TSS (mg/l)	4	4	6	6	4	15
			October 2, 1990			
Sample No 40-	8105	8106	8107/08*	8109	8110	8111
Depth (ft)	0	18	33	0	15	28
Temp (°C)	13 5	12 8	12.5	13 5	13	12.8
Salinity (o/oo)	29 0	30 4	35 1	28 9	30 1	30 4
TSS (mg/l)	1	2	3	1	1	2
			December 26, 1990			
Sample No 52-	8283	8284	8285	8286/80*	8281	8282
Depth (ft)	0	16	28	0	12	22
Temp (°C)	9 2	9 8	10 2	9 1	9 6	10
Salinity (o/oo)	27 0	28 5	28 5	28 0	28 8	29 2
TSS (mg/l)	2	2	3	4	2	2
			March 28, 1991			
Sample No 13-	8070	8071	8072	8073/74*	8075	8076
Depth (ft)	0	19	36	0	15	28
Temp (°C)	8 9	8 4	8 3	8 7	8 4	8 2
Salinity (o/oo)	27 2	28 6	28 8	27 4	28 8	28 6
TSS (mg/l)	2	-	3	2	2	4
			June 19, 1991			
Sample No 13-	8280	8281	8282	8283/84*	8285	8286
Depth (ft)	0	18	35	0	15	30
Temp (°C)	14 5	10 7	10 2	14 5	10 9	10 4
Salinity (o/oo)	NA	NA	NA	NA	NA	NA
TSS (mg/l)	2	2	3	2	4	5

*=Reported as mean of duplicate samples

NA=Not analyzed

Appendix D: Tentatively Identified Organic Compounds

Table D1: Summary of tentatively identified semivolatile organics in settling particulate matter from Thea Foss Waterway collected June 1989 to November 1992 (all concentrations are estimated ug/kg, dry).

Location	Head Near Twin 96" Drains						
Station No.	TF-1						
Sample No.	8096/ 97*	8118	8301	8320	8569	8426/ 27*	8331/ 32*
Collection Date	5-12/89	1-6/90	7-12/90	1-6/91	6-11/91	12/91-5/92	5-11/92
Benzeneacetic acid	na	na	16000	-	-	-	-
Hexadecanoic acid	na	na	49000	49000	11000	9000	220000
Tetradecanoic acid	na	na	-	-	9700	5500	25000
Octadecanoic acid	na	na	-	-	-	-	54000
Methyl tetradecanoic acid	na	na	-	-	-	-	1800
Benzene propanoic acid	na	na	-	-	-	-	35000
Methyl undecanoic acid	na	na	-	-	-	-	6500
Methyl decanoic acid	na	na	-	-	5700	-	-
2-methylbutanoic acid	na	na	-	-	-	-	6600
Phenyl acetic acid	na	na	-	-	-	2500	7500
Oleic acid	na	na	-	-	-	-	21000
Benzene propanic acid	na	na	-	-	-	-	4800
Cholesterol	na	na	66000	-	-	-	-
1-Phenyl ethanone	na	na	-	-	-	1600	-
Bicyclo hexenone	na	na	-	-	-	3600	1700
1H-Indole-5-carbonitrile	na	na	-	-	-	-	1400
2,3-Trimethyl naphthalene	na	na	-	-	-	-	3800
3-Carene	na	na	-	-	-	770	-
Benzaldehyde	na	na	-	-	-	-	1600
Unknown hydrocarbons	na	na	39000	-	1900	5000000	8900
Unknown sterols	na	na	28000	-	-	-	-

*=Reported as mean of two samples

+=Reported as mean of three samples

na=Not analyzed

-=Not detected at unspecified detection limit

Table D1 (continued): Summary of tentatively identified semivolatile organics in settling particulate matter from Thea Foss Waterway collected June 1989 to November 1992 (all concentrations are estimated ug/kg, dry)

Location	North of 15th Street Drain						
Station No.	TF-2						
Sample No.	-	-	8302	8313	8524	8428	8333
Collection Date	5-12/89	1-6/90	7-12/90	1-6/91	6-11/91	12/91-5/92	5-11/92
Hexadecanoic acid	na	na	51000	71000	32000	11000	320000
Tetradecanoic acid	na	na	-	32000	13000	-	120000
Octadecanoic acid	na	na	-	-	6600	-	35000
Octanoic acid	na	na	-	-	-	-	390
Methyl tetradecanoic acid	na	na	-	-	-	-	7300
Methyl decanoic acid	na	na	-	-	-	-	10000
Phenyl acetic acid	na	na	-	-	-	-	4700
Oleic acid	na	na	-	-	47000	-	120000
Benzene propanic acid	na	na	-	-	-	-	400
Methyl octane isomer	na	na	32000	-	-	-	-
Cholesterol	na	na	78000	-	13000	-	-
1-Phenyl ethanone	na	na	-	-	-	1300	-
Cyclohexenone	na	na	-	-	1100	8100	720
2-Hydroxy benzonitrile	na	na	-	-	-	940	-
1 2-Dihydro naphthalene	na	na	-	-	340	-	-
1,4-Methanoaulene	na	na	-	-	-	-	390
7,22-Dienol ergosta	na	na	-	-	7900	-	-
4-Hydro benzaldehyde	na	na	-	-	-	-	330
Benzofuranone	na	na	-	-	-	-	320
3-Hexene-2,5-dione	na	na	-	-	-	-	440
Unknown hydrocarbons	na	na	9400	-	-	5000000	6400
Unknown sterols	na	na.	28000	-	-	-	-

*=Reported as mean of two samples

+=Reported as mean of three samples

na=Not analyzed

-=Not detected at unspecified detection limit

Table D1 (continued): Summary of tentatively identified semivolatile organics in settling particulate matter from Thea Foss Waterway collected June 1989 to November 1992 (all concentrations are estimated ug/kg, dry).

Location	Mouth of Wheeler-Osgood Waterway						
Station No.	TF-3						
Sample No.	8101	8108/ 8117/13+	8303/ 13*	8322/ 27*	8525/ 26*	8429	8334
Collection Date	5-12/89	1-6/90	7-12/90	1-6/91	6-11/91	12/91-5/92	5-11/92
Hexanedioic acid	na	na	-	-	1300	-	-
Hexadecanoic acid	na	na	16000	70000	9800	11000	-
Tetradecanoic acid	na	na	-	25000	12000	-	-
Octadecanoic acid	na	na	-	-	-	8500	-
Methyl undecanoic acid	na	na	-	-	-	-	820
Methyl decanoic acid	na	na	-	-	-	-	3100
Methyl ester tetradecanoic acid	na	na	-	2700	-	-	-
Methyl butanoic acid	na	na	-	19000	-	-	-
Benzene propanic acid	na	na	-	7100	-	-	-
Methyl ester decanoic acid	na	na	-	4900	-	-	-
Methyl octane isomer	na	na	7500	-	-	-	-
Cholesterol	na	na	33000	-	-	-	-
Cholesanol isomer	na	na	8600	-	-	-	-
C10 H14 Isomer	na	na	2900	-	-	-	-
Cyclohexenone	na	na	-	-	-	4200	280
3,2-Cyclohexenone	na	na	-	-	-	840	-
2,3-Dimethyl naphthalene	na	na	-	-	360	-	-
2,3-Trimethyl naphthalene	na	na	-	-	280	-	-
1,4-Methanoaulene	na	na	-	-	59	-	-
3-Carene	na	na	-	-	170	-	-
Benzofuranone	na	na	-	-	-	48	-
Dimethyl trisulfide	na	na	-	-	-	290	-
Unknown hydrocarbons	na	na	10000	-	14000	6000000	1500
Unknown sterols	na	na	18000	-	-	-	-

*=Reported as mean of two samples

+=Reported as mean of three samples

na=Not analyzed

-=Not detected at unspecified detection limit

Table D1 (continued): Summary of tentatively identified semivolatile organics in settling particulate matter from Thea Foss Waterway collected June 1989 to November 1992 (all concentrations are estimated ug/kg, dry).

Location	Mouth near D-Street Tank Farms						
Station No.	TF-4						
Sample No.	8105	8119	8304/ 05*	–	8527	8430	8335
Collection Date	5-12/89	1-6/90	7-12/90	1-6/91	6-11/91	12/91-5/92	5-11/92
Hexadecanoic acid	na	na	33000	–	9600	15000	610000
Tetradecanoic acid	na	na	–	–	13000	–	110000
Octadecanoic acid	na	na	–	–	21000	–	68000
Methyl decanoic acid	na	na	–	–	–	–	5900
Phenyl acetic acid	na	na	–	–	–	–	3000
Methyl ester benzoic acid	na	na	–	–	–	740	–
Gamma-sitosterol	na	na	–	–	1500	–	–
Cholesterol	na	na	62000	–	–	–	–
5,22-Dien-3-o-cholestanol	na	na	–	–	5000	–	–
Cyclohexenone	na	na	–	–	–	3100	2000
4-Methano-1,3 dioxolane	na	na	–	–	15000	–	–
Unknown hydrocarbons	na	na	14000	–	24000	4000000	7800
Unknown sterols	na	na	31000	–	–	–	–

*=Reported as mean of two samples

+=Reported as mean of three samples

na=Not analyzed

-=Not detected at unspecified detection limit

Appendix E: Problem Chemicals in Settling Particulate Matter vs Commencement Bay Sediment Quality Objectives

Table E1: Comparison of problem metals in settling particulate matter from Thea Foss Waterway to Commencement Bay Sediment Quality Objectives (mg/kg, dry).

Location	Head near twin 96" Drains														
Station No.	TF-1														CMB
Period	5-8/89	8-12/89	1-4/90	4-6/90	7-10/90	10-12/90	12/90-3/91	4-6/91	6-9/91	9-11/91	11/91-2/92	2-5/92	5-8/92	8-11/92	Mean	SQO
Cadmium	2.9	1.9	2.5	-	3.1	2.3	2.3	-	-	3.1	2.7	2.6	3.6 j	3.7 j	2.8	5.1
Copper	180	120	140	-	190	150	150	-	-	210	150	160	200	210	170	150
Mercury	0.66	0.40	0.51	-	0.63	0.50	0.55	-	-	0.72	0.79 j	0.57 j	0.76 j	0.68 j	0.62	0.59
Nickel	64	71	81	-	63	80	69	-	-	56	62	54	47	63	65	>140
Lead	370	330	360	-	350	360	400	-	-	380	370	350	340	390	360	450
Zinc	370	410	410	-	340	400	460	-	-	460	460	410	380	490	420	410

Location	North of 15th Street Drain														
Station No.	TF-2														CMB
Period	5-8/89	8-12/89	1-4/90	4-6/90	7-10/90	10-12/90	12/90-3/91	4-6/91	6-9/91	9-11/91	11/91-2/92	2-5/92	5-8/92	8-11/92	Mean	SQO
Cadmium	-	-	-	-	2.1	1.9	-	2.1	2.4	2.8	2.3	2.6	3.1 j	1.5 j	2.3	5.1
Copper	-	-	-	-	160	180	-	230	180	240	170	170	200	190	190	150
Mercury	-	-	-	-	0.61	0.64	-	0.74	0.63	0.90	0.89 j	0.78 j	0.88 j	0.96 j	0.78	0.59
Nickel	-	-	-	-	37	40	-	38	36	35	40	41	36	39	38	>140
Lead	-	-	-	-	240	240	-	270	240	260	260	280	270	290	260	450
Zinc	-	-	-	-	270	260	-	270	260	290	260	280	300	240	270	410

-=No sample (sediment trap was not recovered)

j=Estimated Concentration

CMB SQO=Commencement Bay Sediment Quality Objective, based on environmental risks (EPA, 1989)

[ ]=Exceeds Sediment Quality Objective

Table E1 (continued): Comparison of problem metals in settling particulate matter from Thea Foss Waterway to Commencement Bay Sediment Quality Objectives (mg/kg, dry).

Location	Mouth of Wheeler-Osgood Waterway														
Station No.	TF-3														CMB
Period	5-8/89	8-12/89	1-4/90	4-6/90	7-10/90	10-12/90	12/90-3/91	4-6/91	6-9/91	9-11/91	11/91-2/92	2-5/92	5-8/92	8-11/92	Mean	SQO
Cadmium	2.6	2.4	2.0	2.6	3.0	2.3	-	2.2	2.4	3.1	2.2	2.9	-	3.0	2.6 j	5.1
Copper	210	220	340	210	270	250	-	180	220	310	190	230	-	230	240	150
Mercury	0.69	0.61	0.68	0.79	0.72	0.65	-	0.67	0.6	0.79	0.71 j	1.0 j	-	0.70 j	0.72 j	0.59
Nickel	46	42	43	40	36	41	-	36	33	39	38	38	-	35	39	>140
Lead	250	240	230	250	250	240	-	240	220	271	210	270	-	220	240	450
Zinc	300	320	440	340	360	350	-	280	290	410	270	340	-	310	330	410

Location	Mouth near D-Street Tank Farms														
Station No.	TF-4														CMB
Period	5-8/89	8-12/89	1-4/90	4-6/90	7-10/90	10-12/90	12/90-3/91	4-6/91	6-9/91	9-11/91	11/91-2/92	2-5/92	5-8/92	8-11/92	Mean	SQO
Cadmium	1.4	-	0.9	-	1.4	0.8	0.9	1.4	1.9	1.3	1.3	1.3	1.7 j	1.5 j	1.3 j	5.1
Copper	120	-	140	-	150	130	160	160	130	190	120	130	150	150	140	150
Mercury	0.42	-	0.38	-	0.48	0.36	0.45	0.48	0.35	0.59	0.49 j	0.44 j	0.44 j	0.41 j	0.40 j	0.59
Nickel	35	-	39	-	33	33	37	33	28	32	35	33	31	31	33	>140
Lead	120	-	130	-	160	120	180	160	120	120	120	150	130	130	140	450
Zinc	170	-	220	-	200	170	280	210	160	170	180	200	200	180	200	410

-=No sample (sediment trap was not recovered)

j=Estimated Concentration

CMB SQO=Commencement Bay Sediment Quality Objective, based on environmental risks (EPA, 1989)

[ ]=Exceeds Sediment Quality Objective

Table E2: Comparison* of problem organics and selected additional organics detected in settling particulate matter from Thea Foss Waterway to Commencement Bay Sediment Quality Objectives (ug/kg, dry).

Location	Head near Twin 96" Drains								North of 15th Street Drain								
Station No.	TF-1								TF-2								
Collection Period	5-12/89	1-6/89	7-12/90	1-6/91	6-11/91	12/91-5/92	5-11/92	Mean	5-12/89	1-6/89	7-12/90	1-6/91	6-11/91	12/91-5/92	5-11/92	Mean	CMB SQO
PROBLEM ORGANICS																	
LPAH	9800 j	22000	5700 j	32000 j	1800 j	11000 j	5800 j	13000j	-	-	2500 j	-	250 j	5200	2800	2700j	5200
HPAH	61000 j	77000	36000 j	120000 j	14000	62000 j	38000	58000j	-	-	13000 j	-	-	15000	12000	13000j	17000
Phenol	460 j	600 u	720 u	8500 u	140 u	1300	210 u	530j	-	-	950 u	8200 u	970	260 u	140 u	460	420
4-methylphenol	3100	300 u	360 u	8500 u	140 u	310 u	120 j	720j	-	-	470 u	8200 u	970 u	260 u	110 j	280j	670
Butyl benzyl phthalate	3600	300 u	1600	8500 u	360 u	780 u	1200 j	1300j	-	-	470 u	21000 u	2500 u	670 u	290	480	900
Bis(2-ethylhexyl)phthalate	18000	16000	11000	54000 u	4700 u	18000	11000	15000	-	-	5300	8200 u	1600 u	4600 u	45000 j	25000j	1300
Benzyl Alcohol	1900 u	1500 u	1800 u	na	730 u	1600 u	67 j	67j	-	-	2400 u	na	5000 uj	1400 u	77 j	77j	73
NON-PRIORITY ORGANICS																	
Benzoic Acid	3800 u	6200	2100 j	9400 j	1100 j	46000 j	6500	12000j	-	-	7400	110000 u	970 uj	3400 uj	3700	5600	650
Dibenzofuran	300 j	900	250 j	1100 j	73 j	440 j	260	470	-	-	470 u	8200 u	970 u	300	220	330	540
Diethyl phthalate	420 j	300 u	360 u	8500 u	140 u	310 u	210 u	280j	-	-	470 u	8200 u	970 u	260 u	140 u	140u	200
Dimethyl phthalate	360 j	300 u	360 u	8500 u	140 u	570 j	210 u	360j	-	-	470 u	8200 u	970 u	260 u	140 u	140u	160
Di-n-butyl phthalate	380 u	400	360 u	8500 u	140 u	7000 j	420 u	1500j	-	-	470 u	8200 u	970 u	2000 u	140 u	530u	1400
Di-n-octyl phthalate	720 j	2100	360 u	8500 uj	140 uj	310 uj	510 uj	690j	-	-	470 u	8200 uj	970 uj	260 uj	350 u	510u	6200

*=Only detected values and non-detects below the SQOs were used in calculating mean concentrations
j=Estimated concentration
u=Not detected at detection limit shown
nar=No analytical result
na=Not analyzed
-=No sample
CMB SQO=Commencement Bay Sediment Quality Objective, based on environmental risks (EPA, 1989)
[ ]=Exceeds Sediment Quality Objective

Table E2 (continued): Comparison* of problem organics and selected additional organics detected in settling particulate matter from Thea Foss Waterway to Commencement Bay Sediment Quality Objectives (ug/kg, dry).

Location	Mouth of Wheeler-Osgood Waterway								Mouth near D-Street Tank Farms								
Station No.	TF-3								TF-4								
Collection Period	5-12/89	1-6/89	7-12/90	1-6/91	6-11/91	12/91-5/92	5-11/92	Mean	5-12/89	1-6/89	7-12/90	1-6/91	6-11/91	12/91-5/92	5-11/92	Mean	CMB SQO
LPAH	5100 j	8200 j	3800 j	14000 j	1400 j	5600	3900	6000j	4500 j	5200	3000 j	-	630 j	3300 j	3100	3300j	5200
HPAH	20000 j	18000	16000 j	16000 j	5900 j	17000	18000	16000j	18000	16000	16000 j	-	980	9500	12000	12000j	17000
Phenol	170 j	540 u	400 u	4400 j	89 u	340 u	200 u	930j	68 j	200	1000 u	-	210	170 u	200 u	170j	420
4-methylphenol	170 u	270 u	550	7400 u	350 j	140 u	190 j	280j	3700	140 u	510 u	-	1700 j	170 u	210	1100j	670
Butyl benzyl phthalate	310 j	270 u	370 j	18000 u	230 u	360 u	450	330j	970	140 u	510 u	-	150 u	420 u	1600	630	900
Bis(2-ethylhexyl)phthalate	5800	5000	4100	7400 u	2500 u	4200 u	6200	5300	2200	4500	3400	-	800 u	4200 u	12000	4600	1300
Benzyl Alcohol	860 u	1400 u	980 u	na	460 uj	730 u	200 u	-	690 u	710 u	2600 u	-	310 u	860 u	85 j	85j	73
NON-PRIORITY ORGANICS																	
Benzoic Acid	1700 u	7900	700 j	12000 j	870 j	6500 j	450 u	4700j	1400 u	9700	3200 j	-	860 j	7300 j	5400	5300j	650
Dibenzofuran	350 j	480 j	280	1300 j	95 j	400	310	460j	120 j	300	510 u	-	33 j	160 j	250	230j	540
Diethyl phthalate	130 j	270 u	200 u	7400 u	89 u	140 u	200 u	150j	100 j	140 u	510 u	-	60 u	170 u	200 u	130j	200
Di-n-butyl phthalate	170 u	270 u	270 u	7400 u	89 u	3900 u	200 u	200u	140 u	140 u	510 u	-	60 u	170 u	1500 j	420j	1400
Di-n-octyl phthalate	310 j	610 j	200 u	7400 u	89 u	140 uj	500 uj	310j	140 u	590	510 u	-	60 uj	170 uj	500 u	330j	6200

*=Only detected values and non-detects below the SQOs were used in calculating mean concentrations
j=Estimated concentration
u=Not detected at detection limit shown
nar=No analytical result
-=No sample
na=Not analyzed
CMB SQO=Commencement Bay Sediment Quality Objective, based on environmental risks (EPA, 1989)
[ ]=Exceeds Sediment Quality Objective

Table E3: Comparison of problem metals in bottom sediments collected December 1989 from Thea Foss Waterway to Commencement Bay Sediment Quality Objectives (mg/kg, dry).

Location	Head near Twin 96" Drains	North of 15th Street Drain	Mouth of Wheeler-Osgood Waterway	Mouth near D-Street Tank Farms		CMB
Station No.	TF-1	TF-2	TF-3	TF-4		SQO
Cadmium	3.1	2.0	3.6	1.4	0.4	5.1
Copper	170	140	250	140	89	150
Mercury	0.71	0.84	0.92	0.58	0.09	0.59
Nickel	86	44	46	42	34	>140
Lead	470	500	300	170	140	450
Zinc	520	400	360	190	200	410

CMB SQO= Commencement Bay Sediment Quality Objective, based on environmental risks (EPA, 1989)

=Exceeds Sediment Quality Objective

Table E4: Comparison of problem organics and selected additional organics detected in bottom sediments collected December 1989 from Thea Foss Waterway to Commencement Bay Sediment Quality Objectives (ug/kg, dry).

Location	Head near Twin 96" Drains	North of 15th Street Drain	Mouth of Wheeler-Osgood	Mouth near D-Street Tank Farms		CMB
Station No.	TF-1	TF-2	ST-3	ST-4		SQO
PROBLEM ORGANICS						
LPAH	12000 j	6600 j	3300 j	1800 j	2300 j	5200
HPAH	79000	33000	22000	12000	9900	17000
Butyl benzyl phthalate	2100	11000	340	130 j	74 u	900
Bis(2-ethylhexyl)phthalate	21000	31000	6100	2600	480 uj	1300
NON-PRIORITY ORGANICS						
Dibenzofuran	300	230 j	120 j	80 j	34 j	540
Diethyl phthalate	160 u	260	120 j	140 u	74 u	200
Dimethyl phthalate	220 j	130 j	130 j	140 u	74 u	160
Di-n-butyl phthalate	450	250000	150 u	140 u	74 u	1400
Di-n-octyl phthalate	1800	540	150 u	140 u	74 u	6200

u=Not detected at detection limit shown

j=Estimated concentration

CMB SQO=Commencement Bay Sediment Quality Objective, based on environmental risk (EPA, 1989)

=Exceeds Sediment Quality Objective